UNIVERSITY OF ALBERTA

COMPUTER BASED INSTRUCTION:

EFFECTS OF MATCHED DIGITAL AUDIO ON ACHIEVEMENT, TIME SPENT IN LEARNING AND ATTITUDE TOWARDS HIGH SCHOOL MATHEMATICS

BY

DARLENE REHAAG ©

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and Research in partial fulfilment of the requirements for

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Computer Based Instruction: Effects of Matched Digital Audio on Achievement, Time Spent in Learning and Attitude Towards High School Mathematics here submitted by Darlene M. Rehaag in partial fulfilment of the requirements for the degree of Master of Education.

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ABSTRACT

In the tradition of dual versus single channel research, this field experiment investigated the effects of the inclusion of matched redundant digital audio on achievement in, time spent in learning and attitude towards CBI delivered mathematics at the high school level. Differential effects on students of varying entry learning math performance was also investigated.

Mathematics 10 subjects (N = 82) were assigned to the two main treatment conditions (*CBIaudio*, *CBItext*) by stratified match pairs within three existing classes. Both treatment groups completed the same three lessons of one unit of Math*Tech 10*. Math*Tech 10* is a course in the Alberta curriculum which is delivered by CBI, contains 110 lessons and incorporates 16 self-diagnostic exams. The three selected lesson files for the treatment condition were modified by adding redundant audio (male voice instructions), except for the exams and those portions of the lesson where random generation was used.

Analysis of scores on a math achievement test measuring the objectives of the lessons revealed that assignment to the two CBI delivery modes did not have a significant effect on the overall comprehension and learning mastery of the related mathematical materials. No significant differences between the lower ability students across the two treatment groups were observed.

Several different time measures were addressed in the study. Overall study times were equivalent for main treatment groups but higher ability dual channel students took more time overall than their control group counterparts. Regarding time to complete the practice questions built into each lesson, the higher ability dual channel students took less time to complete the questions with equivalent achievement scores, implying greater learning efficiency.

Overall there were no significant attitude differences between the two main treatment groups. In the dual channel audio treatment condition, lower ability students were generally more positive about learning than the higher ability students. Additional attitude differences were found.

The results suggest that redundant audio, added to Computer Based Instruction to teach high school mathematics, has little effect on achievement but does affect learning time, and attitude formation of students of differing learning ability.

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LIST OF ABBREVIATIONS

ABC	Advice By Computer
CBI	Computer Based Instruction
CMI	Computer Managed Instruction
CML	Computer Managed Learning
CAL	Computer Assisted Learning
CBT	Computer Based Training
CAI	Computer Assisted Instruction
EMS	Entry Mathematics Scores
HEMS	Higher Entry Mathematics Scores (Subjects)
KHz	Kilohertz
LEMS	Lower Entry Mathematics Scores (Subjects)
MB	Megabyte
RAM	Random Access Memory

CHAPTER I: INTRODUCTION

The emergence of more powerful computer hardware and software development tools make it technically feasible to incorporate digital audio speech into interactive Computer Based Instruction (herein, CBI). While technically feasible, little actual research has been undertaken with respect to investigating the educational effects of incorporating digital audio speech on the learning process.

Digital audio speech research has narrowly focused on the mechanics of incorporating digital audio speech into existing text-based applications, the "how to" of digital voice integration. Contemporary research assumes the relative educational effectiveness and desirability of the inclusion of digital audio speech in text-based applications. From a hardware and software perspective, it focuses on discovering the best techniques of incorporating digital audio speech into text-based applications. Areas that have received the most attention for the inclusion of digital audio speech are second language training, distance education, adult literacy, special education, early childhood education and reading programs.

Little research to date has investigated the relative benefits and educational effectiveness of the inclusion of digital audio speech in CBI applications, the "why" of audio integration. Furthermore, very little information is available regarding the educational effect, benefits and desirability of the inclusion of digital audio speech in CBI in core subject areas in mainstream educational programs, especially at the junior and senior high school levels. Specifically, the research has not addressed whether the inclusion/exclusion of digital audio speech constitutes a significant user variable in the enhancement of student achievement and attitudes towards CBI Mathematics learning at the senior high school level.

The Problem and its Setting

Statement of the Problem

What are the main and aptitude-treatment effects of supplementing Computer Based Instruction (CBI) with redundant (matched, full-text) digital audio on *achievement in*, *time spent in learning*, and *attitude towards* CBI delivered mathematics at the tenth grade level? To address these issues, answers to the following subproblems were sought:

Achievement. Does the addition of matched redundant digital audio instructions to text-based CBI lessons:

Subproblem 1) effect the treatment group's (herein, *CBIaudio*) achievement levels on Math*Tech 10* Unit 3 Topic 1?

Subproblem 2) assist subjects with lower entry mathematics scores (herein, *LEMS*) more than subjects with higher entry mathematics scores (herein, *HEMS*) in reaching a higher level of achievement on Math*Tech 10* Unit 3 Topic 1?

Time Spent In Learning. Does the addition of matched redundant digital audio instructions to text-based Math*Tech 10* Unit 3 Topic 1 lessons:

Subproblem 3) significantly effect *CBIaudio's time spent in learning*?

Subproblem 4) yield significantly different effects for the aptitude-treatment groups' (*HEMS* X *CBIaudio* / the single channel comparison group (herein, *CBItext*) and *LEMS* X *CBIaudio* / *CBItext*) *time spent in learning* ?

Attitude Towards CBI Mathematics. Does the addition of matched redundant digital audio instructions to text-based Math*Tech 10* Unit 3 Topic 1 lessons:

Subproblem 5) result in a significant difference in *CBIaudio*'s *expressed attitude* towards CBI Mathematics?

Subproblem 6) result in a significant difference in aptitude-treatment groups' *expressed attitude* towards CBI Mathematics ?

Hypotheses

The following research hypotheses were the focus of the study.

1. There will be no significant differences between *CBIaudio* and *CBItext* on achievement scores on Math*Tech 10* Unit 3 Topic 1.
2. There will be significant aptitude-treatment effects on achievement in favour of *LEMS / CBIaudio* versus *LEMS / CBItext*.
3. There will be no significant differences between *CBIaudio* and *CBItext* on *time spent in learning* Math*Tech 10* Unit 3 Topic 1.
4. There will be significant differences between the aptitude-treatment groups (*HEMS X CBIaudio / CBItext* and *LEMS X CBIaudio / CBItext*) on *time spent in learning*.
5. There will be significant differences between *CBIaudio* and *CBItext* in *expressed attitude* towards CBI Mathematics.
6. There will be significant aptitude-treatment effects with *HEMS/CBIaudio* generally expressing less positive attitudes than *HEMS/CBItext and LEMS* X *CBIaudio* towards CBI Mathematics.

Assumptions of the Study

For the purposes of this study it is assumed that:

1. The sample, which consisted of a population of three classes of Mathematics 10 students from a local high school in a small "bedroom community" in close proximity to a large urban centre in Alberta, is

representative of the full range of abilities found in learners at similar educational institutions across Alberta.

2. The novelty effect associated with the use of the CBI itself was greatly reduced or eliminated by using subjects who were already experienced with computers and who had some degree of familiarity with Math*Tech 10* (without the digital audio component).
3. Grade nine mathematics marks served as a valid instrument with which to rank subjects (by mathematical aptitude) into matched pairs for the assignment to treatment conditions.

Delimitations of the Study

The range of questions that might potentially be included in any CBI digital audio research is immense. While all the following issues are worthy of further investigation, they are beyond the scope of this research study. Therefore the researcher acknowledges the following delimiting factors. This study did not attempt to:

1. investigate the effectiveness of other possible digital audio stimuli - *related*; *unrelated*; *contradictory* (See Chapter II: Literature Review; Section I for an explanation of these terms). The aim was to investigate the effectiveness of the inclusion of *redundant* digital audio (matched, full-text instructions) on CBI Mathematics learning.
2. provide subjects with the option to select/deselect the digital audio stimuli.[1] The subjects in this study, could not turn the audio on or off

[1] Although observed actual behaviour, offering and then electronically tracking subjects' choice and frequency of the use of digital audio CBI, may serve as a reliable measure of attitude (Suppes 1981), providing students with this choice in the context of this study would interfere with the investigation of the *time spent in learning* variable. The study of *expressed attitude* towards CBI Mathematics was a secondary, not primary goal of the research.

or otherwise pre-empt the audio in the *CBIaudio* treatment condition. (For rationale, see Chapter II: Literature Review).

3. pre-screen or post-test subjects for learning modalities strengths. Neither did it solicit feedback as to subjects' expressed preferred learning modalities prior to assignment to treatment conditions.
4. investigate the effects of the inclusion of female versus male voice audio instructions or optional male/female voice audio instructions.
5. measure subjects' expressed attitude change (pre versus post treatment) as a result of having been exposed/not exposed to CBI matched (redundant) digital audio.
6. study the effectiveness of CBI Mathematics per se versus conventional or other available alternate delivery systems.
7. study students' attitude towards computers or mathematics per se. The focus was on students' *expressed attitude* towards CBI Mathematics learning with/without an audio digital speech component. It was included only to aid in the understanding of the effects of the inclusion of audio and was therefore a secondary not primary goal of the research.
8. offer students the choice of the CBI advisement option (now renamed Advice By Computer herein, ABC). Inclusion of an ABC component may have resulted in the production of interaction effects that would serve to further complicate the interpretation of the findings of the study, particularly those concerned with *time spent in learning* (See Chapter II: Literature Review for details).

Limitations of the Study

The findings of this study may not be generalizable to:

1. non-CBI instruction, or CBI topics other than mathematics at the senior high school level.
2. inexperienced CBI students (ie. subjects who have not had earlier

experiences with the operation of a computer and have not had sufficient experiences to become comfortable and familiar with the format of Math*Tech 10* lessons).

3. mature or adult learners who may have access to Math*Tech 10* through distance education delivery systems.
4. students that do not live in and are educated in similar learning environments to the subjects in this study (ie. in a small bedroom community outside of a large urban centre in Alberta).

Definition of Terms

Numerous technical terms and abbreviations are referred to throughout this study due to the nature of digital audio research. Only those terms that required operational definitions for the purposes of this research study have been included in the next section. For clarification of abbreviations not listed in the following, please see List of Abbreviations.

Audio Component; Matched Digital Audio; Matched Digital Audio Instruction; Redundant Digital Audio; Full-Text/Full Audio. For the purposes of this study the preceding terms are used interchangeably. They refer to and are operationally defined to mean the addition of male voice recordings in the following two areas:

1. **audio instructions, directions, explanations and tutorial entries**. Voice recordings of the actual on screen text lesson instructions were simultaneously played as the full-text appeared on the monitor. In the literature, this combination is often referred to as *redundant audio* or *matched audio*.
2. **audio student performance feedback**. When a question was answered correctly in the instructional component of the Math*Tech 10* Unit 3 Topic 1 module, accompanying digitized audio feedback was

"voiced" as it was simultaneously printed to the screen (such as, "That is correct"). If a student keyed in an incorrect response, the correct answer was voiced and displayed simultaneously.

Advice By Computer (ABC) refers to a set of self-check Math*Tech 10* diagnostic tests to help each student assess their learning and performance. The ABC exams identify which objectives have been mastered and what to study in the case of unmastered objectives.

CBIaudio refers to the treatment condition in which students were assigned to complete Math*Tech 10* Unit 3 Topic 1 with full-text screens supplemented with additional redundant matched digital audio instructions and feedback in the lesson component of the module.

CBI Mathematics refers to Math*Tech* 10 Educational Courseware, Version 2.0. (See APPENDIX 15 for a list of Lessons, Topics, Units, and Objectives).

CBItext refers to the comparison treatment condition in which students were assigned to complete the original unmodified Math*Tech 10* Unit 3 Topic 1 with full-text screens (without additional redundant matched digital audio instructions).

Computer Managed Instruction (CMI) "Computer Managed Instruction employs the computer as a record-keeping device and does not provide any direct instruction to learners" but can provide a "diagnostic-prescriptive strategy based on the learner's responses to material stored in the computer system" (Hall, 1982, p.353).

Experienced CBI Learners was operationally defined as learners who have had earlier experiences either at home or at school with the operation of a computer, keyboard and mouse, and have had sufficient experiences to become comfortable/familiar with the protocol of Math*Tech 10* lessons. "Sufficient experiences" was operationally defined as students having had a minimum of one week of Math*Tech 10* lessons prior to participation in the audio research study.

Expressed Attitude was operationally defined as students' total percentage scores on the 42-item Likert-scale attitude questionnaire, Opinion On Learning Mathematics by Computer.

HEMS refers to the sample aptitude subgroup composed of students who achieved Higher Entry Mathematics Scores prior to the commencement of the study. *HEMS* was operationally defined as the subpopulation of Mathematics 10 students who ranked in the top half of the total sample population group. The rankings were based on grade nine final mathematics marks as recorded in their Cumulative Record card.

HEMS/CBIaudio refers to the aptitude-treatment subpopulation group that was composed of students with relatively higher entry mathematics scores who were assigned to the experimental audio treatment condition.

HEMS/CBItext refers to the aptitude-treatment subpopulation group that was composed of students with relatively higher entry mathematics scores who were assigned to the comparison treatment condition.

Initial load time was operationally defined as the total amount of time (in seconds) required to load the *CBIaudio* (or *CBItext*) files from the initial logon to the commencement of each of the three activity lesson modules.

LEMS refers to the sample aptitude subgroup composed of students who achieved ***Lower*** Entry Mathematics Scores prior to the commencement of the study. *LEMS* was operationally defined as the subpopulation of Mathematics 10 students who ranked in the bottom half of the total sample population group. The rankings were based on grade nine final mathematics marks as recorded in their Cumulative Record card.

LEMS/CBIaudio refers to the aptitude-treatment subpopulation group that was composed of students with relatively lower entry mathematics scores who were assigned to the experimental audio treatment condition.

LEMS/CBItext refers to the aptitude-treatment subpopulation group that was composed of students with relatively lower entry math scores who were assigned to the comparison treatment condition.

Level of Achievement/Performance was operationally defined as the total percentage score on a 23-item *Multiple Choice Final exam* on Math*Tech10* Unit 3 Topic 1: Solving Linear Equations.

Practice Exercise time *(Quiz 1, 2* and *3 time)* was operationally defined as the total amount of time (in seconds) taken by individual students to read/hear, comprehend and respond to the *Practice Exercise* questions during the three lesson quizzes in the Math*Tech 10* Unit 3 Topic 1 module. Both *CBIaudio* and *CBItext* completed the original text-only *Practice Exercises*. The three *Practice Exercise* portions of the Math*Tech 10* module, did not include *redundant audio* instructions or any auditory feedback of any kind.

Rank Ordered Matched Pairs. Students' final grade 9 mathematics marks were obtained with permission from the school's Cumulative Record card, prior to the commencement of the audio research study. They were used to rank order subjects by mathematical aptitude into matched pairs within classes before assignment to *CBIaudio/CBItext*.

Time. For the purposes of the audio study, the broader term *time* has been operationally defined and referred to in four ways: *initial load time*, *Practice Exercise time*, *time spent in learning* and *total connect time*.

Time spent in learning. Spencer, (1991) pointed out that *time spent in learning* is a function of time allowed for learning and the student's perseverance in learning. The term, *time spent in learning,* for the purposes of this audio research was operationally defined as the total amount of time (in seconds) taken by individual students to read/hear, comprehend and respond to the text and/or audio instructions during the three lesson or activity portions of the Math*Tech 10* Unit 3 Topic 1 module.

Total connect time was operationally defined as the total amount of time (in seconds) from logon to Math*Tech 10* Unit 3 Topic 1 to logoff taken by each subject throughout the duration of the audio research study.

Need for the Study

Recent advances in technology make it possible to add digital audio speech into CBI. While possible, its impact on learning theory and its related consequences for CBI delivery systems and instructional design has not been fully researched and understood to date.

A review of the related literature reveals two distinct periods of audio instructional design research. Each period is limited by and a function of the available audio technology at the time of the studies involved.

Analog audio instructional design research flourished in the late 1950's and early 1960's in conjunction with developments in audio tape cassette recording technology. Audio-tutorial research investigated the desirability and potential educational effectiveness of the use of analog audio tape cassette technology for instructional purposes. Ultimately, this area of research was eclipsed by two factors:

1. advances in video recording technology which focused attention away from audio to broader considerations of multi-visual instructional design. Film and video tape technologies appeared to hold more promise and constitute more exciting areas of research. Audio and the effects of integrating audio into text-based applications got lost in the shuffle.
2. the limitations of analog audio with respect to the inherent problems of linearity, referability and reviewability. (See Chapter II: Section II for details).

Digital audio instructional design research, which only came into prominence in the last few years with the development of powerful computer hardware and software technologies, is still in its infancy. Although digital audio CBI is being implemented and holds the potential to overcome some of the problems associated with analog audio (linearity, referability, reviewability), little actual research has been conducted to investigate its educational effectiveness.

Significance of the Study

Given the added time and expense of adding digital audio to CBI it is important to ask whether integrating digital audio speech actually enhances the learning process? The issue is not simply one of trying to justify the added development time, equipment and expense. Rather, integrating digital audio into CBI may in fact inhibit and interfere with the learning process (ie. distract the learner; frustrate learners more comfortable with text-based reading modalities; cause the information assimilation process to be slowed down to the point of frustration).

While it is possible to ignore questions of instructional design and educational effectiveness, we do so at our peril. In our rush to market "glitzy" presentations we run the risk of repeating previous mistakes and misunderstandings.

> It is clear, for example that the development of motion pictures and television occurred almost entirely without reference to education or learning theory. (Unwin, 1988, p.283).

Just because we can does not necessarily mean we should integrate digital audio into CBI from an educational perspective. Learning theorists need to explore the potential educational benefits, and under what conditions, that may occur with the inclusion/exclusion of a digital audio component in CBI.

The introduction of computer technology provides new opportunities and means to revolutionize existing instructional methods. As the technology advances, educators may possess the tools that will allow instructional designs to move beyond current text based modes, to include interactive multimedia presentations that combine graphics, video, animation and audio. Classic learning theorists have maintained that a multi-sensory approach to learning generally enhances retention in most situations. Research is required to determine if and under what conditions these theories continue to be supported in light of the new technologies available to us as educators and instructional designers.

CHAPTER II: REVIEW OF THE LITERATURE

Introduction

As outlined in Chapter I, the stated objective of this study was to investigate the main and aptitude-treatment effects of supplementing Computer Based Instruction (CBI) with redundant digital audio on *achievement in*, *time spent in learning*, and *expressed attitude* towards CBI delivered mathematics at the tenth grade level. The audio research literature is examined with respect to each of these three areas.

1. Audio channel stimuli and its potential impact on learner effectiveness.
2. *Time spent in learning* for CBI with combined audio/text (dual channel) versus CBI with text -screens only (single channel).
3. *Expressed attitude* towards CBI Mathematics with and without audio.

Chapter II concludes with a discussion of how the findings, issues, and controversies encountered in the literature review grounds the three hypotheses of the audio research study.

Section I
Audio Channel Research and Learner Effectiveness

> Next to the written word, audio is perhaps the second largest distribution medium for instruction. And yet audio, in general, has been more lightly treated for effectiveness than any other medium. (Unwin, 1988, p. 29)

Section I of this literature review begins with a brief summary of the issues and findings regarding audio research and learner effectiveness. Specifically, it focuses on the inclusion of audio components in various instructional delivery systems. Conclusions reached by both learning channel studies (historical analog audio research) and digital audio speech studies (contemporary audio research) are detailed.

Historical Trends & Issues in Channel Research

Early audio research focused on analog rather than digital audio storage and retrieval technologies. Although the focus of this research study is on the educational effectiveness of the inclusion of digital audio speech in CBI, this literature review would not be complete without an investigation of the historic findings of analog-delivered audio research studies. These studies are referred to as learning channel or communication channel studies.

Channel researchers were concerned with "the organization of information and its presentation to the human senses" (Hartman, 1961, p.235). Relevant channel research includes:

1. Single Channel Superiority (Auditory versus Visual Channel),
2. Dual Channel Learning (Interference or Reinforcement).

Channel Research

> Research on the channels of modern communication media is much older than the media themselves. The media channels, after all, correspond to the human sensory modalities, of which vision and hearing are of principal usefulness. (Hartman, 1961, p. 235)

Single Channel Superiority (Auditory vs. Visual Channel Supremacy). The introduction of alternate educational delivery systems (radio, phonographs, filmstrips, audio tape cassettes etc.) made possible by the development of new communication technologies generated heated debates over the superiority of one individual learning channel over another.

In traditional single channel research design, subjects were randomly assigned to one of two treatment learning conditions. Information to be learned would be presented through the auditory channel (audio stimuli) or the visual channel (visual stimuli). Audio presentations investigated took on a variety of different forms ranging from traditional-style lectures and oral demonstrations, to more "progressive" educational methods such as the use of audio tape cassettes and educational-radio programs, etc. Visual presentations were characteristically comprised of either traditional texts or print-based workbooks, or combinations of visual images such as pictures, slides, prints, graphics, and charts. Information to be learned could range from short nonsense syllables, digits and lists of meaningful words to long passages of prose (Hartman, 1961).

Hartman (1961) presented an excellent summary of the issues, methodologies and problems encountered with single channel research. His findings revealed that audio stimuli offered the following advantages:

1. Speech (one form of audio stimuli) offers greater flexibility such as variations in connotations, nuances ...and are more attention-demanding.

2. Hearing is somewhat more resistant to fatigue than is vision (p.240).

After reviewing the single channel studies to date , Hartman concluded that:

> Audio is a more effective channel than print when the information is simple and easily understood by the subjects and for illiterates and semi-illiterates (e.g., children) regardless of the difficulty of information. Print shows increasing advantage over audio for literate subjects roughly proportional to increasing difficulty in their comprehension of the material (p.240).

He suggested that the variables in single channel audio-print comparisons that seem to be of importance were:

> ...age and intelligence of subjects, the difficulty and meaningfulness of the information presented, and the length of time between presentation of the information and the testing of the information. (p. 236).

Barron's (1991) review of the single channel literature confirms Hartman's earlier findings. She concludes that "studies also agree that neither the audio nor the visual channel is inherently superior to the other" (p. 17).

Dual Channel Learning (Interference or Reinforcement). Comparative single channel research was gradually replaced by dual versus single channel learner effectiveness studies as technological advances made dual channel (combined audio-visual) presentations a viable educational alternative.

Burk's research (1972) is representative of dual channel research. Burk was puzzled by the seemingly contradictory findings to questions as to whether or not the advantages of audio outweigh the disadvantages. On the one hand, his research indicated that "the audible presentation in capturing the accented and emphasized points as well as the speaker's character may engage the learner's attention and so provide for greater learning" (Burk, p.41). However, "average readers may be able to read faster than the average speaker talks" (Burk, 1972, p. 41.)

To investigate these paradoxical findings he compared four presentation modes (audio-verbal, media-paced to printed-verbal, media-paced, to audio-verbal, self-paced to printed-verbal, self-paced) to determine if one mode resulted in any significant learning advantage over any other modes (Burk, 1972, p. v). His results found "no significant differences in achievement" (p. iv).

Hartman (1961a) also reviewed nine experiments that investigated comparisons of simultaneous audio-print presentations with either audio presentations alone, or with print presentations alone.

> With regard to the comparisons of simultaneous audio-print with print, seven studies supported the simultaneous presentation, and two found the presentations equivalent (p. 243).

In his own separate research (1961b), he found the audio-print combination to be the most consistently effective of the seven possible combinations of the three learning channels tested (ie. text, pictorial, audio). He concluded that:

> It is apparent that a simultaneous audio-print presentation is more effective than either audio or print alone when the information is simultaneously presented is redundant (p.244).

To explain these findings, a theory referred to as Cue Summation Theory, was postulated. It argued that:

> Dual-channel presentations result in more learning than single-channel presentations because the number of stimuli or cues is increased (quoted in Barron, 1991, p.18).

Alternate Explanations of Multichannel Learning. Numerous theoretical debates have arisen in response to the multichannel versus single-channel studies conducted during this time period. In addition to cue summation theory, two other theories were proposed. These were Broadbent's (1958) single-channel processing theory and Hsia's (1968a) central limit theory. In the following section, the two theories and supporting research studies are summarized.

Single-channel processing theory. The main advocates of single channel processing theory were Travers (1964 & 1970), Holliday (1971) and

Severin (1967). In their research they attempted to establish the validity of the theory that maintained:

> There is only one channel to higher centres of the brain; therefore, dual-channel transmission can be equal to, but not greater than, the single-channel processing. In fact, if both stimuli arrive at the same time, information jamming may occur and cause the dual-channel effectiveness to be less than either of the single-channel's (Barron, 1991, p. 18).

In general, their studies tended to show no significant learning advantage of combined audio/print presentations. Severin also pointed out the importance of the researchers use of terms to clearly differentiate between *redundant, relevant, related* and *contradictory* dual-channel or multichannel information. They challenged other multichannel researchers to attempt to support cue summation theory to disprove the alternate explanation they offered. One multichannel researcher who attempted to prove that this theory was "demonstrably insufficient" was Hsia (1968b, p. 326). The next section looks at his findings and the theories he supported.

<u>Central limit theory</u>. Hsia's (1968b) study established six conditions in differing combinations of channel treatments (audio, visual, and audio-visual) and noise factors (noise and no noise), found that:

> ...data showed that both communication efficiency and dependability were higher in the AV channel than in the A and V channels alone (p. 342).

Hsia asserted that:

> ...if the combined amount of information of audio and visual stimuli exceeds the upper limit of the central nervous system capacity, then both selection processes and interference take place: yet so long as neither audio nor visual stimuli exceeds the upper limit of the central nervous system, an audio-visual

> presentation is generally a more efficient method of presenting communication materials (p.253).

In a later study on seventh grade students, Hsia (1969) further concludes that intelligence is a factor in the effects of redundancy. He maintained that the simultaneous audiovisual channel presentation of identical or high-redundancy information would make it possible to raise low intelligence subjects to a level of performance as high as that of high intelligence subjects. This finding appears consistent with Eraut's (1989) observation that highly structured presentations have often been found to improve performance for low aptitude learners, whereas inflexibility (or lack of learner control) may be a hindrance to high achievers.

The difference in achievement levels reached by students with varying ranges of intelligence or aptitude, may be a function of interaction effects between *time spent in learning* and individual student ability levels. The literature seems to suggest that higher achievers may be capable of estimating and assuring a better match between *time needed for learning* and *time spent in learning* without it being forced on them externally (ie. by the CBI instrument itself).

Tennyson's (1981) work on learner control indicated that all learners do not always make wise choices when judging when to continue on with a learning activity. However, if given advisement, Tennyson demonstrated that most learners can effectively control their instruction. High aptitude learners on the other hand, are generally more capable of managing their own learning, with and without advisement.

In summary, each of the three theories, cue summation theory, single channel processing theory and central limit theory, although seemingly contradictory, were supported on numerous occasions by multichannel learning studies. For a concise summary, see Barron (1991). To understand why such contradictory and inconsistent findings were reported, the next section of this literature review attempts to identify potential factors that could account for these differences.

Inconsistencies in the Historic Audio Literature. Analog channel research studies often resulted in inconsistent and contradictory findings. Hartman (1961a) suggested that the inconsistent results were due to:

1. inconsistent use of the terms in the literature, and
2. test channel bias.

Inconsistent use of the terms in the literature. Hartman (1961a) maintained that terms audio, audio channel, audio stimuli, etc. were not used consistently in the literature. In later multichannel research, this tendency was sometimes corrected. According to Hartman:

> Since the advent of motion pictures and television, however, it has become customary to subdivide the visual channel into two components: a pictorial channel (non-verbal) and a print channel (visual verbal)... Less frequently, the auditory channel is divided into two components: auditory verbal (spoken words) and auditory non-verbal (sound effects and music). The tendency to define channels according to the kind of information presented indicates the nature of the interest of the researcher in communication (Hartman, 1961, p. 235).

A second inconsistency related to the lack of precision with respect to how combined information delivery terminology was defined (Hartman, 1961). Two channels may present:

1. *redundant information* (ie. the same word appears printed and simultaneously spoken),

2. *related information* (ie. a pictorial representation of an object is shown while a verbal description of the object is given),
3. *contradictory information* (ie. the simultaneous presentation of a printed word "woman" and the spoken word "man"), and
4. *unrelated information* (ie. a picture of a cat combined with the audio presentation of the word "twenty").

According to Hartman, the imprecise use of audio terminology contributed to the inconsistent and often contradictory findings of channel research.

<u>Test-channel bias</u>. Hartman identified a second problem in doing comparative channel research. He found the occurrence of test-channel bias in many of the studies he analyzed. Test-channel bias is said to occur if:

> ...the situation in which information is presented for learning and the situation in which the learning is tested are not the same, results may be biased in favour of the test-mode channel.

Interestingly enough, even when many dual-channel studies did not control for test-channel bias, Hartman (1961b) claimed:

> ...the simultaneous presentation (of audio and text) proves more effective despite the fact that the additional cues are not present when the information is tested via single channel (p.244).

Severin (1967a) also attempted to explain the inconsistencies between the findings and the theories. He concluded that:

> Contributing factors are poor sampling techniques, weak designs, lack of randomization, poor controls, lack of probability statements, and test-channel bias (quoted from Barron, 1991, p. 25).

Before these issues could be resolved, multichannel research took on another turn. In the rush to experiment with more powerful multichannel media (ie. television, video cassettes, laser disks, computers etc.), single and dual channel research fell out of favour. Whether single versus dual channel modes of presentation is more effective no longer constituted an interesting area of research.

> It is clear, for example that the development of motion pictures and television occurred almost entirely without reference to education or learning theory. Historically, audiovisual materials have been used primarily for group or mass presentation without explicit regard to individual differences in learning ability. (Unwin, 1988, p. 283)

Consequently, educational multichannel researchers began to focus their attention on new questions such as:

1. What is the most effective combination of channels? For whom and under what learning conditions? In what learning environments?
2. What variables need to be considered in the design of effective multichannel presentations?

Instructional design implicitly assumed that multichannel learning was there to stay. Rather than arguing about the superiority of one channel over another or dual versus single channel effectiveness, debates emerged over the best or most learner effective combinations of multichannel presentations. This redirected focus led to a third series of multichannel learning research. For a summary of the multichannel combinations literature, see: Spencer (1991). [2]

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[2] Although these studies are of great importance to educational instructional designers, and have contributed much to our current understanding of the use of "*related*", "*unrelated*" and "*contradictory*" combinations of audio (music and sound) and visual (text, graphics, stills, animations and video), they are beyond

Contemporary Trends in Digital Audio Speech Research.

With the advent of more sophisticated computers, analog audio research all but disappeared. Research efforts were redirected towards exploring the most effective combinations of audio, visual and text-based presentations.

> Communication technologies such as computers, videotapes, audiotapes, and satellites are far ahead of our ability to use them effectively and efficiently in an instructional design. Even simple things such as recognition of achievement may have to be reexamined and new mechanisms developed for their acceptance. (Unwin, 1988 p. 296)

During the transition period, some audio dual channel research attempted to integrate the power of the digital computer with analog audio tape cassette recorders and laser disks. The analog recordings on the audio tape cassettes and laser disks were controlled by signals embedded in the computer program. However, due to the inherent underlying linear nature of the analog technology, retrievability, reviewability and program delivery time limited the effectiveness of these types of hybrid delivery systems. It was not until three new digital audio speech production technologies emerged (computerised text-to-speech synthesis, Linear Predictive Coding (LPC), and digitized human speech) that audio channel research could effectively transcend the aforementioned analog audio limitations.

Given the recent introduction of digital audio speech production technologies, it is not very surprising that much of the contemporary digital audio research effort has been directed towards how to integrate speech-to-text and text-to-

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the stated scope of this study which deals with the instructional effectiveness of "*redundant*" audio and text in combination versus text presentations alone. This study is in the tradition of the second form of channel research (ie. visual channel-text screen versus audio-visual information in combination).

speech into educational presentations. Other contemporary research has focussed its attention on when to use this emerging technology for educational endeavour.[3] To date, very little research has been directed towards investigating, from a learner effectiveness perspective, why the addition of digital audio speech would be warranted.

A review of contemporary digital audio speech literature reveals that the use of digital human speech in CBI education at the junior and senior high school levels in core subject areas (ie. Mathematics, English, Science, Social Science), is noticeably lacking. Due to the interest and rising popularity of adult retraining programs (CBT) and distance education, a few recent studies involving digital audio research have been conducted at the post-secondary level. One would expect to see further studies as digital audio technology matures and becomes available for application development and field testing.

The next part of Section I examines the issues identified in the only study located at the time of this study on the educational effectiveness of supplementing a CBT tutorial with redundant digital speech audio.

Effectiveness of Digital Audio in Computer-Based Training. Ann Barron (1991) in her unpublished doctorate thesis at University of Central Florida, investigated the effectiveness of adding digital audio to an existing computer-based training (CBT) tutorial. In her field test, 60 college students were

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Digital audio speech research in the following areas are abundant: special education, early childhood education, adult literacy, second language training. This research to date, however, has not focused on investigating the educational effectiveness of integrating digital audio. Rather it has narrowly focused on the "how" and "when to". This audio research study attempted to empirically investigate the "why to" in order to determine if the addition of audio speech significantly impacts learner effectiveness.

randomly assigned to one of three treatment groups:

1. Text-only delivery,
2. Full-text and totally redundant audio delivery,
3. Partial text (bulleted) with full audio delivery.

Each group completed a 20 minute CBT tutorial on CD-ROM technology. Her research study findings of the learner effectiveness variable indicated:

> ...that the computer-based training with and without audio were equally effective. No treatment group demonstrated superior gains over the other group (p. 72).

She offered two explanations as to why the level of achievement was the same whether one experienced one or two channels of communication.

> 1. ...this finding could provide support to Broadbent's theory that multiple inputs do not enhance communication...
>
> 2. ...the posttest was unable to adequately discriminate between different levels of learning. Perhaps a longer tutorial or a more difficult posttest would have revealed more variation (p. 73).

Barron's CBT digital audio study recommends further field testing with a longer tutorial time.

Summary, Audio Channel and Learner Effectiveness

The findings of both historic and contemporary channel communication research are somewhat inconclusive. In general, the research fails to empirically substantiate or disprove that learner effectiveness is enhanced by combining audio with text. This may be due to inherent research design limitations; by focusing on main treatment effects rather than looking for the variables that cause significant interaction effects, the studies may be doomed to reporting findings of no significant differences. As Unwin (1988) states:

> Although one of the central problems in everyday instruction has been how to pay regard to the individual differences between learners by choosing appropriate educational and instructional measures, educational researchers in general and media researchers in particular, attempted to tackle this problem by studying the collective manifestations of cognitive principles. In the majority of these studies the learning individuals were reduced to an "average learner" and individual differences were not taken into account. If, however, through the use of undifferentiated averages, a virtually heterogeneous group is treated as a homogeneous entity, all eventual differences between individuals are cancelled out in the overall results (p.368).

Based on the literature reviewed and in light of the preceding, hypothesis one states that there will be no significant differences between *CBIaudio* and *CBItext* on achievement scores on Math*Tech 10* Unit 3 Topic 1.

The audio studies reviewed do suggest, however, that due to the potential interaction effects of increased *time spent in learning* and student aptitude, the addition of redundant digital audio may impact on certain individual student's performance. This phenomena is explained in further detail in the next section. This has led to the formulation of the second hypothesis that states "there will be a significant aptitude-treatment effect on achievement in favour of *LEMS / CBIaudio*".

Section II

Audio-Time Issues

> ...a student does not learn from the media. He learns from a presentation form. Media do little more than deliver the information to be learnt in whatever presentational form previously decided upon.
>
> Tosti & Ball, 1969, quoted in Unwin, 1988, p.374

This section reviews the audio literature with respect to the second question of the audio research proposal. It outlines what audio instructional designers and educational researchers have found regarding:

1. the ways the term, *time*, is referenced in the literature, and
2. the factors that influence the amount of time required for an individual learner to comprehend and respond to CBI interactions (ie. *time spent in learning*).

The section ends with a brief discussion of the implications of the related findings.

Time Terminology

In any study involving CBI, the *time* variable must be either controlled or operationalized in that it often reflects a wide range of meanings for audio researchers. Various connotations of the term in the audio literature reviewed include:

1. *access-time*,
2. *narration-time /program delivery time*,
3. student learning time/ student instruction time, herein, *time spent in learning* (inconsistently referred to as *delivery time*).

Access Time is "the time a disk drive takes to locate information stored on the disk" (Curtin, 1989, p.733). *Access time* is subject to wide variability depending on the capabilities of the selected computer hardware, any attached peripherals (ie. CD ROM players) and the presence of a network in the field (school) test site.

Narration-time. In an audio study, *narration-time*, or time needed to load and subsequently deliver the speech audio with accompanying full-text screens is also a function of several factors that could change from situation to situation as a function of access time parameters outlined previously. Some research studies such as Barron (1991), refer to this measurement of time as (program) *delivery time* with and without audio. The use of this term is inconsistent in the literature. Misinterpretations as to the design of the research can result.

Time Spent in Learning. Caroll's (1963) model of school learning and later well known educational theorist, Benjamin Bloom's, relates mastery of subject matter with two major variables in learning:

1. *time needed in learning*, which depends on student aptitude, the quality of instruction and the student's ability to understand instruction

2. *time spent in learning*, which depends on the time allowed for learning and the student's perseverance in learning" (Spencer, 1991, p. 18)

It is important to remember that *narration time* is not necessarily equivalent to the *time needed in learning* or *time spent in learning* (just as *text-screen display time*, traditionally referred to as *program delivery time*, is also not equivalent).

In recognition of this problem, the CBI learner is often given control of *time spent in learning* by indicating their readiness to continue with the lesson by pushing on the built-in return key. Earlier CBI research (Tennyson, 1981) on *time needed in learning* indicates, students are not always the best judges of the amount of time or review they need in order to master a concept. Recent studies on CBI with advisement show promise in helping individual students with this problem without relinquishing the freedom of learner control CBI typically offers (Evans, 1991).

Literature on *Time Spent in Learning*

The review of the literature on *time spent in learning* suggests that individual learners vary significantly in the time taken to read/hear, comprehend, and respond to the text and/or audio instructions. The channel literature reviewed indicated that this difference could be attributable to at least four factors:

1. *rate* of text/audio presentation of material to be learned,
2. *referability* of text/audio presentation,
3. *reviewability* of text/audio presentation,
4. *interaction effects* with individual student attributes.

Rate of Text/Audio Presentation

> It is widely assumed that materials which force all learners to go through the program at the same rate are likely to be too slow and inefficient for some learners and too fast and ineffective for others. Indeed, it has been observed that in some self-paced programs, slower learners require five to six times as long as faster students to master a set of learning materials. Thus, providing for individualization in rate of instruction seems generally advisable, especially when the learner population is heterogenous (Eraut, 1989, p. 400).

Although the previous quote addresses the rate of presentation variable with respect to text presentations, the rate of presentation must also be recognized as a factor in combined auditory-visual delivery systems.

In his review of research on speech compression effectiveness, Unwin (1988) indicates that:

> ...most persons can listen and comprehend at rates much higher than the average speaking rate. For instance, the average oral reading rate is around 175 words a minute and yet the average person can listen at a rate of 300 words per minute (p.36).

He also states that when an average person listens to an audio tape cassette at a normal presentation speed that there is "...a tendency to be lulled into a lack of attention, particularity if the audio recording is long" (p.36). However, in experiments conducted with analog speech compression technologies, where the subject was free to adjust the listening tape to rates which they felt they could handle, he noted that "listener attention was heightened" (p.37). Rates were typically boosted from "twice to two and a half times the normal rate" without a loss in pitch (p. 37). He did caution however:

> ... to keep in mind the amount of new information provided in a given time frame. While a hundred new bits of information can be compacted into a minute, how much the average listener can attend to and remember is a critical factor to consider (p.37).

In the future, enhanced user control and adjustment capabilities of digital speech compression technologies may improve the rate of presentation of audio instruction to enhance its overall effectiveness and efficiency. Current technology does not support this option if one is combining digital audio with existing CBI modules.

Referability of Text/Audio Presentation. Another presentation variable that effects *time spent in learning* is stimulus duration or length of time the presentation remains intact, from persistent to transient.

Hartman (1961) in his comparative channel research, reported that non-referability and reviewability were two main disadvantages of audio stimuli:

> Auditory stimuli are essentially temporal in nature. Visual stimuli can be presented sequentially or simultaneously. Auditory stimuli have poor referability. It cannot be held continuously for closer review like visual stimuli can (p.240).

By its inherent nature, audio stimulus is not *referable* in the same sense as text-screen presentations. With the introduction of digital technology, audio stimulus is now more readily accessible and *reviewable* than was the case with traditional analog delivery systems. The findings and inconsistencies found in the dual-channel research should therefore be open to reinvestigation in light of the introduction of new digital capabilities.

Barron's (1991) research represents one of the few contemporary audio studies to reopen the issue of dual-channel superiority. Her findings with respect to this issue follow.

Reviewability of Presentation

Reviewability of audio presentation. Barron (1991) in her CBT college level audio study, included a provision to make audio reviewable based on individual learner demands. She included a repeat audio (button) on 40 instructional screens and tracked its use for her Full-text/Full-audio and Partial-text/Full-audio treatment groups. Her findings revealed that students in the Full treatment chose this option a total of 5 times while students in the Partial group elected this option 4 times (p. 61).

The fact that students in both audio treatment groups (Full and Partial text in combination with Full Audio) did not elect to review audio (ie. repeat the audio stimulus), may reveal something about the nature of the learning strategies employed by dual (audio/text) versus single text channel learners.

Barron's findings about the three treatment groups' use of the review screen (text) option add an interesting twist regarding *reviewability* as a factor in *time spent in learning.*

<u>Reviewability of screen (text) presentation</u>. Barron (1991) embedded the option to *review* (text) on every screen in all three treatment conditions. Her results revealed that students in the Text treatment chose to review a total of 47 times, compared to Partial treatment with 35 and Full treatment with 22. Although the amount of review time was not statistically significant, Barron felt it may be practically significant.

She speculated that the phenomena observed may be due to different learning strategies employed by students in each treatment group; that is, students in the text group were more likely to skim through the instructional material and then review as needed to answer the follow-up questions (p. 73). Students in the Full and Partial treatment conditions, may have listened and/or read the material more slowly and thoroughly, and were therefore less likely to review screens or repeat the audio.

<u>Interaction Effects with Individual Student Attributes</u>. Barron's speculation that the students in her study may have been using different learning strategies, may also be explained by an alternate scenario. The results observed may be due to the presence of interaction effects between individual student attributes and the forced increased *time spent in learning* by the very nature of the CBTaudio treatment condition itself. Stated another way, the presence of audio itself may force certain (not all) individual students to persevere longer in the learning and focus on the task at hand rather than merely skimming over the information erroneously believing they have read and comprehended the material fully. This theory would be in keeping with Tennyson's (1981) studies on advisement in which he demonstrated that most

learners were not good judges as to the amount of time needed to learn a specific objective, when they were given control of the length of time they would spend in learning on the computer. Further studies are needed to determine if this proves to be the case.

Studies on CBI/CAI Tutorial Treatment Times with and without Audio. Suppes (1981) conducted a long term series of studies (1961-1981) on university student preferences for computer-assisted instruction with audio. He reported that treatment groups did not significantly differ on *time spent in learning* with and without (synthetic computerized speech) audio. Interestingly enough, however, subjects perceived the Audio/Full-text tutorial as "taking longer" (See Chapter II, Section III for details).

Barron's (1991) results appear to contradicted Suppes' earlier findings. (She did not mention Suppes' work in her literature review.) In her study, she reported that there was a significant difference in mean time required to complete the tutorial among the three treatment groups with the Text-only version requiring the least time on task. She speculated that this difference may be attributed to the pacing that is inherent in audio. It may also be due to the short length of the CBT tutorial utilized in Barron's study (ie average CBT tutorial time was approximately 18 minutes whereas Suppes measured time in his study over several months of classroom lab work).

Kozma (1991), in Learning with Media, suggests that knowledge of subject matter is another important variable in determining the effectiveness of the learning with text, audio or video, for individual students. He claims that:

> People who are very knowledgeable about a particular domain can process information at a much faster rate and more strategically with text than they can with audiotape or video, suggesting text would suffice for these learners. However, people

> who are novices to the domain are likely to benefit from the ability to slow the rate of information processing, regress over text, and move back and forth between text and pictures as they are presented in books (p.194).

If Kozma's suggestions are applied to this audio research study, it would seem reasonable to hypothesize that some students, especially *LEMS* students, might benefit from the slower rate of presentation associated with the combined audio/text presentation format. For others, their pace of processing information may fall far above (some *HEMS* learners) or far below (some *LEMS* learners) the inherent pace of the *CBIaudio* presentation. For students in the last two situations, the additional audio could prove to be a negative factor in their mathematics learning. Barton & Dwyer's (1987) research studies on adults appears to support this theory. They reported that redundant audio only helped adults in the high intelligence group. They speculated that the forced pace of the audiotape might have caused interference for the low intelligence group.

Implications of *Time Spent in Learning*

What are the implications of the *time spent in learning* variable for this audio study? Let us discuss two hypothetical students at each end of the learner-aptitude continuum. If Student A, a speed reader and *HEMS* subject were assigned *CBItext*, the parameters that would influence the minimum time needed to work through the instructional component, would be:

1. the hardware/network access time itself,
2. the CBI software (Authorware Professional 1.7.1 herein, AP) run-time package,
3. the time built in by the embedded screen wait times. (This is a function of the CBI Math developer's decision in the original text-screen version),

and

4. the time needed by the learner to reflect upon and key in his/her responses.

If the same Student A were assigned to *CBIaudio*, #1 and #2 and #4 above would remain constant. But #3 is most likely to be different in the two treatment conditions. That is, Student A may be ready to proceed before the audio portion of the instructions had been fully delivered and the return key option appeared on screen.[4]

However, if Student B was a *LEMS* subject and a slow reader and or had lower levels of reading proficiency and was assigned the same two treatment conditions, it is possible that no significant differences in the two treatment times may be observable. That is, Student B may require more, the same, or even less learning time (#4) in the module with audio *(CBIaudio)* as opposed the module without audio (*CBItext*).

Summary, Audio-Time Issues

In light of the preceding, the study included *time spent in learning* as a variable worthy of further investigation in audio research. The other variables, *access time* and *narration time/program-delivery time* were

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4 Barron (1991) programmed for this event. She gave the Full Text/Full-Audio and the Partial Text/Full Audio treatment groups the ability to "pre-empt" the audio before it was "finished reading". Her studies revealed that although it was an option, few college students elected to use it. Most waited for the audio to completely finish before pushing the wait button. It is for this reason that in this audio research study, the accompanying audio has not been set pre-empt. The objective of this study was to further investigate Barron's finding that students with full audio accompaniment tend not to scan backwards and repeat text screens as often as students in Text-only group do.

controlled for by the nature of the selected experimental design. The inherent nature of audio presentations in combination with individual student differences, should account for any differences in *time spent in learning* that might be observed. By electronically capturing how long each student spends on the instruction component of the CBI module with audio (*CBIaudio*) and without audio *(CBItext)* and by comparing results by matched pairs in each aptitude group (*HEMS / LEMS*) across treatment groups and within treatment groups, an accurate snapshot of how the inclusion of redundant audio effects students' *time spent in learning* should emerge.

Based on the literature reviewed, hypothesis three stated that there will be no significant differences observed between main treatment groups (*CBIaudio* and *CBItext*) on *time spent in learning* Math*Tech 10* Unit 3 Topic 1. Hypothesis four, which addressed the variability of individual learning needs stated that there will be significant differences observed between the aptitude-treatment groups (*HEMS X CBIaudio / CBItext and LEMS x CBIaudio / CBItext*), on *time spent in learning*.

Section III

Effects of Audio on *Expressed Attitude* Towards CBI Mathematics

> Societies have always been shaped more by the nature of the media by which men communicate than by the content of the communication.
>
> Marshall McLuhan, Quentin Fiore
> <u>The Medium is the Massage</u>

Section III reviews the literature that addresses the variables and issues related to the third question posed by this research study; namely, the impact of the inclusion/exclusion of audio on *expressed attitude* towards CBI

Mathematics. The CBI audio-attitude literature review examines:

1. student preferences in the use of audio in computer-based delivery systems,
2. speculations as to how these factors in turn might effect the attitude of the learner towards CBI with audio.

Audio Use in Computer-Based Delivery Systems

Studies on students' *expressed attitude* towards CBI with a digital audio human speech component are relatively scarce or non-existent (Barron, 1991, p. 39). The literature search to the time of this study, was only successful in locating one relevant audio study. Laddaga, Levine & Suppes conducted a series of extensive studies on *Student preferences for Computer-Assisted Instruction with (synthesized) audio* during 1968-1980. One could infer from the students' observable free choice of the audio option of an intact CAI course, how they must have felt about the addition of audio to CAI.

It should be noted that the following audio research by Suppes was based on the addition of computer-synthesized audio using the Microcoded Intoned Speech Synthesizer to a college level Introduction to Logic course. Students may have a very different reaction to CBI with human voice digital audio components at a high school level.

In the first of a series of experiments described by Suppes (1981), college students were randomly assigned to audio-display combinations or display only treatment groups for the initial segment of the study and then reversed for the second portion. After completion of both segments, on the subsequent unit, the students were given a choice at each logon as to which mode they would utilize.

> In general, after a moderately long period of mixed choices, most students chose predominantly one presentation mode. The split between those choosing audio predominantly, and those choosing display-only, was roughly even (p 403).

Suppes (1981) conducted another study to establish a more precise indication of the proportion of college students that preferred audio when given a choice. In this study, he found that about one half of his students used a great deal of audio (more than 80% of their total time was spent with the audio turned on), whereas about one third of his students used very little audio (audio was turned on less than 20% of their total time).

In a later experiment with four treatment groups which received medium or long forced exposure to either display only or audio/display combinations, results, though inconclusive, "... did indicate that the amount of time of forced exposure to audio increases the percentage of audio use during the later period of free choice." (p.403).

He also recommended that "...whenever possible, it seems highly desirable that both modalities be offered, with free choice of their use left to the individual student". The preceding supports the need for further audio research on individual differences across treatment groups as well as differences between groups. Suppes felt his series of studies demonstrated strong individual differences in preference for a visual or auditory mode of presentation (p. 429).

Learner Attitude Towards CBI with Audio

Suppes (1981) collected evaluations (initially in the form of questionnaires and later as an additional on-line 14-question multiple choice survey) from the students participating in a series of studies on student preference, as expressed by the students' selection of audio or display mode.

His findings with respect to the *time spent in learning*, indicated that students' perception of the length of time spent in the audio treatment condition was generally described as longer. Comments such as "audio took too long" or "non-audio lessons were a great deal faster than audio lessons" reflected these perceptions. Ironically, in actual fact, the same studies demonstrated that there was virtually no difference in the amount of time students spend in the course corresponding to using audio or display. Total time in the course and also time spent doing derivations seem to be independent of whether audio or display mode is chosen for most of the work (p. 428).

In a later study, Barron (1991) found that overall university student perceptions of her CBT tutorial were highly positive across all levels of treatment, ie. Full-text alone; Full-text/Full audio; and Partial text/Full audio (p. 74). This finding supports the CBI research conducted earlier (without an audio component) by Kulik, Kulik & Cohen (1980), that exposure to CBI produced positive effects on the attitudes of college students towards instruction and the CBI subject matter. Bangert-Drowns (1985) and Lee's (1990) studies at the secondary level also found students' attitudes were generally positive towards CBI. Although an audio component was not included in the last three studies cited, one would expect to see similar results with the *HEMS/CBItext* and *LEMS/CBItext* aptitude groups in this audio study.

Barron (1991) also found that:

> The only factor on the perception questionnaire that was significant across treatments was the response to the "computer programs make me nervous and uncomfortable" item. The Text group agreed with this statement more than the other two

treatments. Because the questionnaire was administered as a posttest treatment, it may be that the addition of audio for the other two treatments had an affect of lowering students' anxiety levels (p. 75). [5]

In another non-audio CBI study, Rosen, Sears & Weil (1987) found that students who expected poor grades had greater discomfort while using a computer than those who expected higher grades. If one combines the findings from the last two studies, this could suggest that *LEMS* subjects may have less positive attitudes towards CBI without audio (*CBItext*) than with audio (*CBIaudio*) if the audio component does indeed increase their comfort levels as suggested by Barron. As discussed earlier on in this chapter, the research also suggests that the reverse may hold true for the *HEMS* treatment group. Specifically, *HEMS* learners may find the relatively slow pace of the audio interfering and distracting and thus not comforting. It seems reasonable then to hypothesize that some of the *HEMS* students are likely to express a dislike for the audio component of CBI Mathematics and that they may generally have a less positive attitude towards CBI Mathematics than their comparison group counterpart (*CBItext / HEMS)*.

In summary, students' overall *expressed attitude* towards CBI Mathematics with (*CBIaudio*) and without audio (*CBItext*) should be expected to generally be positive. Research indicates that there may be a wide variation of personal reactions to the length of time the audio takes to access (and initially load) and

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The stated secondary focus of this study was to investigate the effect that the addition of an audio component has on the students' *expressed attitude* towards CBI. However for those interested in understanding subjects' expressed attitude towards CBI in general, an examination of the literature pertaining to students' expressed attitude towards computer use for instruction (without audio) reveals that students are generally positive towards CBI. For further information, see Barron (1991) pages 37-40 or Barnes (1990) p. 98-145.

to the perceived usefulness of it to the individual learner. *HEMS* may generally be more likely to find it too slow and distracting, whereas *LEMS* may generally find its presence helpful and comforting.

Therefore, based on the literature reviewed, hypothesis five states that there will be a significant difference between *CBIaudio* and *CBItext* in *expressed attitude* towards CBI Mathematics. Hypothesis six states that there will be a significant aptitude-treatment effect with *HEMS/CBIaudio* generally expressing less positive attitudes towards CBI Mathematics.

Summary, Chapter II

The analog and digital audio channel studies with respect to learner effectiveness were generally inconclusive due to the inconsistent use of the related audio terminology, poor sampling techniques, weak research designs, failure to test for aptitude interaction effects, and test-channel bias. The three channel learning theories summarized, cue summation theory, single-channel processing theory and central limit theory, have yet to be consistently empirically validated by the research studies.

The literature indicated that *time spent in learning* would neither significantly increase or decrease across the two main treatment conditions. However, the research did indicate that for individual students, the addition of matched digital audio may result in an increase in *time spent in learning*. This forced increase in *time spent in learning* may interact to positively effect the same student's performance levels. This effect is more likely to be observed within the sample group of *LEMS* students than within the *HEMS* sample group.

The literature on students' *expressed attitude* towards CBI Mathematics revealed that students generally view CBI with and without audio in a positive manner. Individual students may perceive the audio treatment (*CBIaudio*) as involving a longer length of time to be delivered. However, this perception may not always match the actual *time spent in learning* by the same individual student. A wide range of perceptions as to the usefulness of the audio (both positive and negative) is to be expected.

CHAPTER III: METHODOLOGY

> Media research to date forces us to the conclusion that we know neither how to measure the psychological effects of media nor how to adapt them to the goals and functions of education.
>
> Unwin, 1988, (p. 282)

The purpose of this research study was to investigate the main and aptitude-treatment effects of supplementing Computer Based Instruction (CBI) with *redundant* (matched, full-text) digital audio on *achievement*, *time spent in learning*, and *expressed attitude* towards CBI Mathematics at the tenth grade level. Chapter III describes the methodological design and procedures utilized in order to carry out this investigation. Specifically, Section I describes the sample population, subject confidentiality assurances, the general experimental design and treatment conditions, sampling procedures, and assignment of subjects to treatment groups. Section II, describes the specific data collection, treatment and analysis with respect to each of the six hypotheses and related subproblems. A description of the instruments used to collect the required data is included were applicable.

General Research Design and Methodology

This research design used a field-experiment. A two-factorial design (ability X treatment) across three dependent variables *(achievement in*, *time spent in learning*, and *expressed attitude* towards CBI Mathematics) was employed.

Subjects

The target population of this audio research study is persons studying Alberta Education Mathematics 10 through computer based instruction delivery systems. The available population at the time of this study was severely restricted due to the limited number of educational institutions with computer laboratories that matched the minimum system requirements.

The initial study sample for the CBIaudio research consisted of 89 students from three Mathematics 10 classes at a local high school (in a small bedroom community adjacent to a large urban centre). Two students dropped out of Mathematics 10 prior to the commencement of the actual study for reasons unrelated to the study; one student was in the hospital at the time of the study and three students were absent on one or more days of the study for reasons unrelated to the research. One student chose not to participate in the study. The final study sample was 82 of which 35 were male and 47 female.

Two Mathematics 10 teachers (one female and one male) with prior experience in Math*Tech 10,* volunteered to participate in the CBI audio study. Students were grouped into classes by mathematical aptitude (ie. strong, average and weak mathematical learners) prior to the study as per standard school procedure. Although the mean mark indicates that, in general, the classes were grouped by overall ability (TABLE 1), all three classes had students with a full range of mathematical achievement as measured by their final grade nine mathematics marks.

TABLE 1
Sample Classes' Grade Nine Mathematics Final Marks

Class	Lowest mark	Highest mark	Mean mark
Class A	69.3 %	96.3%	85.2%
Class B	45%	91%	66.4%
Class C	45%	94%	65%

Class A, the honours mathematics or academic challenge class consisted of 33 students, 32 of which were in the final study sample (15 male and 17 female). The general criteria for placement in this class were:

1. high grade nine final marks,
2. a recommendation from the former mathematics teacher, and
3. subject to scheduling concerns.

The second teacher taught both the second and third class in the study. Class B, the "mid-group" or "average group" consisted of a cross-section of 30 students (13 male and 15 female) with a wide range of abilities. The final sample group from this class consisted of 28 students. Two of the students took Mathematics 10 in the previous school year but did not receive a passing final mark and elected to repeat Mathematics 10 the following school year. Eight of the students took Mathematics 13 in the previous school year and had elected to take Mathematics 10 the following school year. The remaining 18 students were taking Mathematics 10 for the first time.

The third class, Class C, was composed of 26 students, 22 of which were in the final study sample (7 male and 15 female). Six students in the final study sample had taken Mathematics 13 in the previous school year. Four students had previously passed Mathematics 10 and were upgrading their marks. The other 12 students were taking Mathematics 10 for the first time.

Students' Rights And Assurances

The general nature and purpose of the research was explained by the researcher and/or classroom teacher prior to the distribution of the consent forms. Students and their guardians were invited to sign a consent form prior to the students' voluntary participation in the audio research study. Informed consent, confidentiality and the right to withdraw at anytime from the research study without penalty was ensured. (See APPENDIX 1: Letter of Consent). One student exercised this right and elected to opt out of the study prior to its commencement. The student was in the room at the time of the study and worked on Math*Tech 10* lessons assigned by the classroom teacher.

Independent and Dependent Variables

The two independent variables were:

1. the subject's exposure to the treatment condition of dual *(CBIaudio)* or single *(CBItext)* channel Math*Tech 10* Unit 3 Topic 1 lesson presentations and
2. mathematical aptitude as measured by final marks in grade nine mathematics (*HEMS / LEMS*).

The dependent variables investigated were:

1. *achievement* levels attained as measured by the scores on the end of Unit 3 Topic 1 *Multiple Choice Final Exam*.
2. *time spent in learning*, as measured by the total time in seconds spent on the instructional portion of Math*Tech 10* Unit 3 Topic 1 Lessons 1,

2 and 3.

3. *expressed attitude* towards CBI Mathematics as measured by the total percentage score of weighted responses to a 42-item Likert-scale attitude questionnaire.

Math*Tech 10*: Instrument Description

Math*Tech 10* is the name given to a CBI version of the Alberta tenth grade mathematics curriculum.

> Originally designed for distance delivery, Math10 has been found useful in conventional classrooms with a wide range of students and instructors. There are several components to Math10, including Tutorial Computer Assisted Instruction (CAI), diagnostic and prescriptive testing or Computer Managed Instruction (CMI), final evaluative examinations, a classroom management system, and a roistering system to roster students. (Math*Tech 10 TM*, QuickStart Manual, page 1)

The curriculum consists of 8 Units organized into 110 lessons (one per objective).

> Lessons use an *interactive* and *engaging* approach which involves students in learning, provide practice and extra *practice items*, a performance *score* and a system to *navigate* within each lesson.(page 1)

For a complete list of all 8 Units and the related skills and concepts covered, see APPENDIX 15.

Instructional Content

The audio study dealt with one subsection of Math*Tech 10* Unit 3: Equalities and Inequalities. Specifically it focussed on the first three lessons and objectives from Unit 3. These were:

Topic One: Solving Linear Equations

<u>Activity One:</u> Translate English sentences into algebra.

<u>Activity Two:</u> Solve and verify linear equations with integral coefficients.

<u>Activity Three:</u> Solve and verify linear equations with rational coefficients.

Math*Tech 10* Modifications

For the purposes of this audio study, the Math*Tech 10* Unit 3 version for Authorware Professional 1.6 was utilized in its origin screen design, instructional content and feedback. The following modifications with permission were made:

Stand-alone (versus networked version) modifications. The original networked version of Math*Tech 10* (for both *CBIaudio/CBItext* editions) was modified for delivery in a stand-alone fashion on each individual hard drive. Necessary modifications to the original file path (ie. where to load Mathematics 10 Unit 3 files and save individual data record files) were made and loaded onto the 30 individual hard drives in the test-site Lab prior to the commencement of the actual audio research study.

Multiple Choice Final Exam modifications. Normally students would be expected to work through the entire Math*Tech 10* Unit 3 before completing the test. Since this audio study was limited to research on Topic 1 only, an extra written *Multiple Choice Final exam* was administered after the completion of the first 3 lesson activities. Since this exam was adapted with permission from Advice By Computer it was necessary to disable access to the original ABC component. The entire Unit 3 and accompanying

ABC unit in its original text-only mode was made available to the school test-site lab at the completion of the study.

Audio treatment group modifications. The male voice audio of on screen text instructions and student performance feedback was digitized using a MacRecorder. After extensive pretesting of various combinations of sampling and compression rates in conjunction with the specific hardware/software parameters of the MacIntosh and Authorware Professional environment., the 11 KHz sampling rate was selected. This sampling rate offered the best available quality voice recording given the test-site parameters (4MB RAM, 20 MB hard drive, 512K cache). As noted by Barron (1991), the 11KHz sampling rate exceeds acceptable industry standards for male voice recording (p. 48).

The digitized audio files were added to the original *CBItext* module. The *CBIaudio* files were simultaneously played as the full-text appeared on the monitor. *Redundant* audio was only added to the three instructional lesson components not to *Practice Exercises* or any other part of the original CBI Math 10 unit. Separate *CBIaudio* and *CBItext* AP Run-time versions of Unit 3 Topic 1 were packaged and loaded onto to designated *CBIaudio / CBItext* work stations. With the exception of the preceding, the *CBIaudio* and *CBItext* modules were identical in every way. Program modifications resulted in differential file sizes (*CBIaudio* = 17 MB / *CBItext* = 1,164 K).

Treatment Conditions

The two main treatment conditions were:

1. the experimental condition (*CBIaudio*) in which subjects completed Math*Tech 10* Unit 3 Topic 1 with redundant digital audio instructions in combination with full-text screen instructions (dual-channel learning), and

2. the comparison group (*CBItext*) in which subjects completed Math*Tech 10* with the original full-text screen instructions (single-channel learning).

The four groups are listed in TABLE 2.

TABLE 2
Main and Aptitude Treatment Conditions

Learning Channel	Main effects	Aptitude Group 1 (HEMS)	Aptitude Group 2 (LEMS)
Dual	*CBIaudio*	*HEMS/CBIaudio*	*LEMS/CBIaudio*
Single	*CBItext*	*HEMS/CBItext*	*LEMS/CBItext*

Research Study Protocol

The classes met for five 67 minute sessions during a one week period. To control for the influence of the Hawthorne effect, students had a minimum of one to two weeks of prior experience with Math*Tech 10*. During the week(s) prior to the study's commencement, the classroom teacher and/or the researcher helped the students familiarize themselves with networked Math*Tech 10* protocol. In addition to this pre-study Math*Tech 10* experience, students had prior familiarity with computers with other applications either at school or at home.

The protocol for logging on/off of an individual hard drive, adjusting the audio volume control, plugging in the earphones, and accessing lessons was demonstrated to each class by the researcher before assignments to *CBIaudio/CBItext* conditions were announced.

During the actual audio study, instruction was primarily by computer based instruction (CBI). The researcher was available to deal with any technical malfunction that occurred with the computer and/or the actual Math*Tech 10* program. The classroom teacher was available to provide individual assistance to subjects upon request. Teachers made every effort to encourage the students to attempt the CBI lesson in its entirety first on their own before requesting additional help with the new concepts being introduced.

Subjects progressed through Lessons and Practice Exercises at their own rate throughout the week. Each subject was allowed to decide when to move on to the next lesson, review a lesson and/or upgrade *Practice Exercise* scores. Subjects were however, expected to take the end of topic *Multiple Choice Final Exam* at the posted date. Some students elected to use additional computer lab time available during lunch hours and after school. The extra time logged was included in calculations of *time spent in learning*, *initial load time*, *Practice exercise time* and *total connect time*.

After the three CBI lessons, *Practice Exercises* and attitude questionnaire were completed, students were given an opportunity in a final class to receive tutoring by the classroom teacher. They were encouraged to take notes regarding key concepts in Lesson 1, 2 and 3 and to review these notes in preparation for the end of topic *Multiple Choice Final Exam*. They were also encouraged to attempt related homework questions in their Mathematics 10 textbook and to study at home for the final exam which was written during the next scheduled class the following week.

Headphones were worn by the *CBIaudio* subjects to minimize distractions between experimental conditions. Students had the option to wear the headphones provided by the researcher or their own radio/cassette/CD earphones. Care was taken to instruct the teachers and students on the proper procedures needed to set the volume control at a low setting before the audio research initially commenced. Reminders regarding the importance of this action and instructions on how to do so, were reviewed by the researcher at each class logon time. Individual assistance was also given for any student that requested or required it.

Assignment of Sample to Treatment Conditions

Subjects were randomly assigned to one of the treatment conditions using a stratified matched pairs design. Stratification procedures were as follows:

1. Grade 9 final mathematics scores as recorded on students' cumulative record cards (CUM) were consulted to determine entry mathematics scores (EMS). Subjects were placed in relative EMS rank order position *within* each class from highest to lowest. Students who had completed either Mathematics 13 or Mathematics 10 in the previous school year were noted and matched into pairs in an attempt to control for prior mathematics background experience.
2. A toss of a coin was used to determine *HEMS* Subject #1's placement in *CBIaudio*. Matched pair *HEMS* Subject #2 was assigned to *CBItext*. Alternate assignment to treatment conditions followed for the remainder of students in all three classes resulting in 41 matched pairs.

Subject Confidentiality

After subjects completed Math*Tech 10* Unit 3 Topic 1, computerized student performance records and Practice Exercise scores were transferred to floppy disks and latter to a separate Dynatek 45MB removable hard disk. The floppy disks and/or any backups made were stored securely under lock and key when not in direct use for analysis to ensure all subjects' confidentiality, anonymity and privacy. New subject identification numbers were assigned to each subject's raw data. Original raw data is currently stored under lock and key and will only be consulted if verification of results becomes necessary.

Data Collection, Treatment and Analysis

General Data Treatment and Analysis

Initial analysis of the treatment effects on the three dependent variables were conducted at the following three levels. All statistical test were evaluated at the $p \leq 0.05$ level.

Level 1: Main effects. Tests were run between the two main treatments groups to determine the presence of main effects.

Level 2: Aptitude effects: Tests were run between *HEMS X CBIaudio/CBItext* and *LEMS X CBIaudio/CBItext* respectively to determine the effects of aptitude on the dependent variables and to test for the presence of any aptitude-treatment interaction effects.

Level 3: Within treatment effects: Comparisons between *HEMS* and *LEMS* learners within *CBIaudio* and *CBItext* respectively, were conducted to test for possible subtle changes in and/or polarization of treatment effects.

Subproblem 1 and 2: Achievement

Data Collected. To investigate Subproblem 1 and 2 primary data regarding *Multiple Choice Final exam* scores was collected. Additional secondary data from computerized student performance records for *Practice Exercises* scores was obtained to supplement interpretation of the achievement and *Practice*

Exercise time findings.

Data Treatment and Analysis. Three tests on *Multiple Choice Final Exam scores* were conducted: a t-test for paired samples to test for main effects (H1), a two-factor ANOVA to test for main, aptitude and interaction effects (H2) and a one-way ANOVA on LEMS across the treatment groups to test specific subpopulation effects (H2).

To assure reliability of the dependent variable achievement instrument, a Cronbach Alpha test was conducted on *Multiple Choice Final Exam* scores. It had a reliability level of 0.78. To ascertain the validity of the *Multiple Choice Final Exam*, two Mathematics 10 teachers at the pilot high school initially screened, reviewed and approved the inclusion of the final 25 test items and multiple choice answers.

Subproblems 3 and 4: Time Spent in Learning

Data collected. To investigate Subproblem 3 and 4, primary data (hour:minute:second) required to tabulate *time spent in learning* was electronically captured on the subject's individual hard drive at pre-established points in Lessons 1, 2, and 3 by embedded commands. Additional secondary data required to tabulate the total number of seconds with respect to *initial load time*, *practice exercise time* and *total connect time* was also captured to aid in the interpretation and understanding of time as a variable.

Data Treatment and Analysis. Clock times at the predesignated check points (ie. logon, initial audio/text file load, Lesson start time, Practice Exercise start time, logoff) were used to tabulate the total number of seconds *spent in learning* for each of the 82 subjects. Four tests on *time* *spent in learning* were conducted: a t-test for paired samples to test for main effects (H3), a two-factor ANOVA to test for main, aptitude and interaction effects (H4) and two separate ANOVAs on *HEMS* and *LEMS* within *CBIaudio* and *CBItext* (H4). Similar tests were repeated for each of the other three time related variables, respectively.

Impact and Control of Related Time Variables

To complete discussions on *time spent in learning* as a variable, an explanation of how other related *time* variables were controlled for is warranted.

Control of Related Time Variables. Two possible confounding variables, *access time* and *narration-time* were controlled for in the following way.

Access time. In this audio study, *access time* to Math*Tech 10* files due to inherent hardware/peripheral constraints should be equally distributed across both treatment conditions (*CBIaudio/CBItext*) in that subjects used similar computers: a MacClassic.

Load time is a second type of *access time* that might act as a confounding variable in an audio study. In an attempt to control for the variance in *load time* due to assignment to *CBIaudio* or *CBItext*, a variable was embedded to electronically record the number of seconds needed to *initially load* the opening screens of Lessons 1, 2, and 3 in both treatment conditions until the start of the actual lesson screen. It was hoped that this would help provide a more accurate picture of the actual *time spent in learning* as opposed to the time spent waiting for the computer to do its relatively lengthy *initial load*. Findings with respect to this variable are presented under Additional Findings.

Narration-time effects (time needed for the narrator to pronounce the words presented on the screen) should equally effect all subjects (*HEMS/LEMS*) *within* the *CBIaudio* treatment condition. Since the subjects were paired by entry mathematics scores (EMS) before assignment to treatment conditions, the confounding effects of this variable should have been equally controlled for and distributed within treatment conditions.

Subproblems 5 and 6: Attitude Towards CBI Mathematics

Before outlining the data location, collection, and treatment with respect to the fifth and sixth subproblems, a brief outline of the instrument used to measure *expressed attitude* towards Math*Tech 10* is included.

Attitude Scale Instrument Description. The study questionnaire was adapted with permission from Opinion On Learning Math By Computer.

> The instrument has 42 items, each of which is answerable in a 5 scale Likert-type format ...each item is classified into one of five categories (A-E) ...The 5 subscores are designed to measure the student's opinion toward:
> A. the instructional strategy,
> B. the personalization of CBI,
> C. individual reaction,
> D. interest in the subject matter, and
> E. technical operation of equipment (Szabo, 1988, p. 1).

Four additional questions were added to the original survey. Question 43 and 44 documented subjects' experience with computers in general and familiarity with the protocol of Math*Tech 10* prior to the commencement of the audio study. Questions 45 and 46, gave subjects the opportunity to describe in short answers what they liked best or least about Math*Tech 10* Unit 3 Topic 1 Lessons 1, 2 and 3. These short answer questions were included to collect feedback to be used in the formative development of future Math*Tech 10* modules. Responses have been passed on to the current developers of Math*Tech 10* for consideration.

Rationale for the selection and interpretation of the attitude instrument. The questionnaire itself did not directly measure attitude towards the use of audio. It was not modified to include explicit questions regarding the subjects' attitudes and experiences with the audio component. It was hypothesized that *CBIaudio and CBItext* should have expressed different reactions to Math*Tech 10* based on their differential experiences of Math*Tech 10* Unit 3 Topic 1. Consequently, one should be able to infer that any significant differences in the responses to any items on the attitude questionnaire was a function of the differences in treatment conditions.

There were certain advantages and disadvantages of electing to measure attitudes towards audio indirectly. The advantages were:

1. An existing attitude survey could be utilized thus making it unnecessary to undergo the lengthy development and field test time required if a new audio and CBI Mathematics attitude survey were to be utilized for the purposes of this research.
2. The identical attitude questionnaire was administered to both treatment (*CBIaudio*) and comparison (*CBItext*) groups, thus avoiding the difficulties that would have been encountered if a comparison between the treatment group's actual experiences and reactions to the CBI audio component and the comparison group's hypothetical speculation about their attitude towards the inclusion of an audio component, were undertaken.

The main disadvantage of this approach was that in the formative development stage, feedback about actual reactions to Math*Tech 10* audio inclusion might have proven insightful. However, as stated in the delimitations of this study, the attitude component of this research was a secondary not primary focus of this study.

Cronbach alpha tests completed indicated that the attitude instrument had a reliability level of 0.92. Because of the nature of the attitude instrument, no attempt was made to establish the validity. It was noted however, that many of the test items were similar in nature to the items included in Barron's (1991) Student Perception Questionnaire. Forsyth (1991) and Poohkay (1994) used similar instruments in their research studies.

Data Collected. To investigate Subproblems 5 and 6, primary data comprising 82 subjects' responses to the attitude questionnaire were elicited and collected. The data was needed to describe and analyze students' *expressed attitude* towards Math*Tech 10*. The attitude questionnaire was administered in class after *CBIaudio* and *CBItext* had completed Math*Tech 10* Unit 3 Topic 1 Lessons 1, 2 and 3 and *Practice Exercises* (Quiz 1, 2 and 3) but before they had completed the *Multiple Choice Final Exam*.

Data treatment and analysis. Subjects' responses to Opinion On Learning Math By Computer were tabulated from the original surveys and entered into a spreadsheet and transferred to a statistical program for analysis. Subjects files were assigned unique ID numbers. Original surveys were placed in envelopes and locked securely away as promised. At the completion of the audio study and related thesis defence, they will be destroyed.

Scores on the 42 Likert-scale questionnaire items were directionally recoded when necessary, and weighted, totalled and converted to percentage scores to obtain an overall measure of expressed positiveness towards Math*Tech 10*. Four tests on the standard total percentage scores means were conducted: a t-test for paired samples to test for main effects (H5), a two-factor ANOVA to test for main, aptitude and interaction effects (H6) and two separate ANOVAs on HEMS and LEMS within *CBIaudio* and *CBItext* (H6). Post hoc investigations were conducted on the 42 individual questionnaire items to determine if subtle or polarization of effects occurred.

CHAPTER IV: RESULTS

This study investigated the effects of the inclusion of matched digital audio on students' overall *achievement in*, *time spent in learning* and *expressed attitude* towards Mathematics Ten when taught by Computer Based Instruction (CBI). Effects of the three preceding variables on two aptitude subpopulations (*HEMS/LEMS* X *CBIaudio/CBItext*) were also analyzed.

Description of Results

In keeping with the format of the previous chapters, the results of the data analysis are presented by Subproblems 1 to 6 respectively. Before presenting the results, tests completed to assure the equivalency of treatment groups (*CBIaudio/CBItext*) and proper identification of sample subpopulations (*HEMS/LEMS*) prior to the commencement of the research study, are outlined.

Verification of Main Treatment Groups' Pre-study Equivalency

An ANOVA on mean grade nine final mathematics marks by treatment revealed that *CBIaudio/CBItext* did not differ significantly prior to the commencement of the audio research study. TABLE 3 contains a summary of the results.

TABLE 3
Summary Table of Analysis of Variance on Grade 9 Final Marks by Treatment

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	6.85	6.85	.03	.86
Within Groups	80	17686.91	221.09		
Total	81	17693.76			

GROUP	N	MEANS	MINIMUM	MAXIMUM
CBItext	41	73.12	45.00	96.00
CBIaudio	41	73.70	45.00	96.30

Verification of Aptitude Groups' Pre-study Equivalency

A one way ANOVA on mean grade nine final mathematics marks by mathematical aptitude revealed that *HEMS/LEMS* represented two unique, distinct subpopulations with respect to entry mathematics scores (EMS) based on grade nine final mathematics marks. TABLE 4 contains a summary of the results.

TABLE 4
Summary Table of Analysis of Variance on Grade 9 Final Marks by Mathematical Aptitude

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	12968.69	12968.69	219.58	.00
Within Groups	80	4725.07	59.06		
Total	81	17693.76			

GROUP	N	MEANS	MINIMUM	MAXIMUM
HEMS	40	86.30	78.00	96.30
LEMS	42	61.14	45.00	77.30

Verification of Aptitude Treatment Groups' Equivalency

Equivalency of aptitude-treatment groups, (*HEMS* X *CBIaudio/CBItext* and *LEMS* X *CBIaudio/CBItext*) was verified by the results of two separate ANOVAs on mean grade nine final mathematics marks. TABLES 5 and 6 contain a summary of the results, respectively.

The results of both ANOVAs confirmed that at the commencement of the audio research study, *HEMS/LEMS* were assigned equally to the *CBIaudio/CBItext* treatment conditions.

TABLE 5
Summary Table of Analysis of Variance
of *HEMS* 's Grade 9 Final Marks by Treatment

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	7.83	7.83	.36	.55
Within Groups	38	830.74	21.86		
Total	39	838.57			

GROUP	N	MEANS	MINIMUM	MAXIMUM
CBItext	20	85.86	78.00	96.00
CBIaudio	20	86.74	78.00	96.30

TABLE 6
Summary Table of Analysis of Variance
of *LEMS* 's Grade 9 Final Marks by Treatment

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	.86	.86	.01	.93
Within Groups	40	3885.64	97.14		
Total	41	3886.50			

GROUP	N	MEANS	MINIMUM	MAXIMUM
CBItext	21	61.00	45.00	76.00
CBIaudio	21	61.28	45.00	77.30

Achievement

Subproblem 1: Main Effects and Achievement

Based on findings from the literature reviewed, hypothesis one stated:

> There will be no significant differences between *CBIaudio* and *CBItext* on achievement scores on Math*Tech 10* Unit 3 Topic 1.

Hypothesis one was tested using a t-test for paired samples on *Multiple Choice Final Exam scores*. TABLE 7 contains a summary of the findings.

TABLE 7
t-Test for Paired Samples on *Multiple Choice Final Exam Scores*

No of Pairs: 41	DF: 40	t-value: -.06	2-tail Sig: .95
GROUP:	MEAN	SD:	SE of MEAN:
CBIaudio	64.83	18.17	2.84
CBItext	65.00	17.50	2.73

Results tabled do not provide sufficient grounds on which to contest research hypothesis one's postulation that the inclusion of matched redundant digital audio will have no significant impact on achievement levels attained for Math*Tech 10* Unit 3 Topic 1.

Subproblem 2: Aptitude Effects and Achievement

Hypothesis two stated,

> There will be a significant aptitude-treatment effect on achievement in favour of *LEMS/CBIaudio*.

Two tests were conducted to test hypothesis two. First, a two-factor ANOVA tested for main, aptitude and interaction effects. Findings are summarized in TABLE 8.

TABLE 8
Summary Table of Two-Factor Analysis of Variance for
Multiple Choice Final Scores

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F	P
Treatment *CBIaudio/CBItext*	1	10.94	10.94	.09	.77
Ability *HEMS/LEMS*	1	159.26	159.26	1.26	.27
Ability X Treatment	1	157.89	157.89	1.25	.27
Error	77	9742.37	126.52		

Secondly a one-way ANOVA on *Multiple Choice Final Exam* scores for *LEMS* across treatment conditions (*LEMS* X *CBIaudio/CBItext*) was conducted. TABLE 9 contains a summary of the results.

As TABLES 8 and 9 reveal there is not sufficient evidence to support research hypothesis two which postulates that *LEMS*'s achievement scores will significantly increase as a result of treatment effects associated with the addition of matched redundant digital audio instructions to text-based CBI lessons.

TABLE 9
Summary Table of Analysis of Variance of *LEMS* Multiple Choice Scores by Treatment

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	107.29	107.29	.45	.51
Within Groups	40	9546.98	238.67		
Total	41	9654.27			

GROUP	N	MEAN	SD	SE	MIN.	MAX.
CBItext	21	55.78	13.64	2.98	32.41	80.56
CBIaudio	21	52.58	17.07	3.73	24.54	84.26

Time Spent In Learning

In an attempt to understand *time spent in learning* as a variable, four tests were conducted. Each is discussed in turn.

Subproblem 3: Main Effects and Time Spent in Learning

Hypothesis three stated,

> There will be no significant differences between *CBIaudio* and *CBItext* on *time spent in learning* Math*Tech 10* Unit 3 Topic 1.

A t-test for paired samples on *time spent in learning* was conducted. The variable used to measure *time spent in learning* was the number of seconds each subject required to complete the lesson portion (with and without audio) of each of the three activity lesson modules before beginning the corresponding *Practice Exercise* portion. TABLE 10 contains a summary of results.

TABLE 10
t-Test for Paired Samples on *Time Spent in Learning*

No of Pairs: 41	DF: 40	t-value:	1.41	2-tail Sig:	.167
GROUP:	MEAN	SD:	SE of MEAN:		
CBIaudio	4421.69	1370.22	214.00		
CBItext	4064.78	1460.18	228.04		

The results of the t-test for paired samples on *time spent in learning* indicated that mean times for *CBIaudio* and *CBItext* did not differ significantly. Thus, research hypothesis three which postulated no significant differences on *time spent in learning* due to treatment conditions is supported in this study.

<u>**Subproblem 4: Aptitude Effects and Time Spent in Learning**</u>

Hypothesis four stated,

> There will be significant differences between the aptitude-treatment groups (*HEMS* X *CBIaudio/CBItext* and *LEMS* X *CBIaudio/CBItext*) on *time spent in learning*.

To test hypothesis four, three tests were conducted. Each is discussed in turn.

A two-factor ANOVA was conducted to test for the presence of main, aptitude and interaction effects. TABLE 11 contains a summary of its findings.

TABLE 11
Summary Table of Two-Factor Analysis of Variance
of *Time Spent in Learning* (Seconds)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F	P
Treatment *CBIaudio/CBItext*	1	3310693	3310693.2	2.12	.15
Ability *HEMS/LEMS*	1	1827572	1827572.0	1.17	.28
Ability X Treatment	1	3381197	342.90	1.48	.15
Error	77	120436315	1564107.98		

The two-factor ANOVA did not reveal any significant main, aptitude or interaction effects on *time spent in learning*. This was not the case when two separate ANOVA's were conducted on each of the two aptitude groups, *HEMS* X *CBIaudio/CBItext* and *LEMS* X *CBIaudio/CBItext*, respectively.

TABLE 12 outlines the findings of the ANOVA of the mean *time spent in learning* for *HEMS* learners by treatment condition.

TABLE 12
Summary Table of Analysis of Variance on *HEMS's Time Spent in Learning* (Seconds)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	5689680.37	5689680.37	4.32	.045
Within Groups	38	50026384.88	1316483.81		
Total	39	55716065.26			

GROUP	N	MEAN	SD	SE	MIN.	MAX.
CBItext	20	3371.50	969.12	216.70	1530.00	5773.0
CBIaudio	20	4125.80	1301.45	291.01	2584.00	6910.0
Total	40	3748.65	1195.25	188.99		

TABLE 12 reveals, *HEMS* learners did differ significantly on the amount of *time spent in learning* depending on assignment to treatment condition ($p<.05$). This analysis provided sufficient evidence to reject the null hypothesis of equivalency of groups on this variable. As would intuitively be expected, it did take a significantly longer time for *HEMS CBIaudio* to work through and complete the three Math*Tech 10* Unit 3 Topic 1 lessons.

TABLE 13 outlines the findings of the ANOVA of the mean *time spent in learning* for *LEMS* learners by treatment condition.

TABLE 13
Summary Table of Analysis of Variance
on *LEMS's Time Spent in Learning* (Seconds)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	4885.91	4885.91	.00	.96
Within Groups	40	88171427.24	2204285.68		
Total	41	88176313.15			

GROUP	N	MEAN	SD	SE	MIN.	MAX.
CBItext	21	4725.05	1560.00	340.42	1836.00	6929.0
CBIaudio	21	4703.48	1405.34	306.67	2134.00	7672.0
Total	42	4714.26	1466.51	226.29		

As TABLE 13 indicates, *LEMS* learners did not differ significantly on the amount of *time spent in learning* in *CBIaudio* and *CBItext*. There is not sufficient evidence to reject the null hypothesis of equivalency of groups on this variable. *LEMS* tended on average to spend equivalent time on working through the three Math*Tech 10* Unit 3 Topic 1 lessons independent of the treatment conditions.

In summary, in the case of HEMS, there is sufficient grounds to support research hypothesis four regarding the impact of the inclusion of redundant digital audio on *time spent in learning*. However, there is not sufficient grounds to support hypothesis four with respect to LEMS on this variable.

Attitude Towards CBI Mathematics

A 42-item Likert scale attitude questionnaire was completed post treatment exposure (*CBItext/CBIaudio*) and pre *Multiple Choice Final Exam* completion. Weighted scores on the 42 questionnaire items were totalled and converted to percentage scores to obtain a measure of overall positiveness towards CBI Mathematics.

Subproblem 5: Main Effects and Expressed Attitude

Hypothesis five stated,

> There will be a significant difference between *CBIaudio* and *CBItext* in *expressed attitude* towards CBI Mathematics.

It was tested using a t-test for paired samples on percentage scores of expressed attitude. TABLE 14 contains a summary of the findings.

TABLE 14
t-Test for Paired Samples on *Expressed Attitude Scores*

No of Pairs: 41	DF: 40	t-value: .32	2-tail Sig: .75
GROUP:	MEAN	SD:	SE of MEAN:
CBIaudio	58.38	10.78	1.68
CBItext	57.71	8.79	1.37

Results revealed that the mean percentage *expressed attitude* scores for the *CBIaudio* and *CBItext* groups did not differ significantly. Based on statistical findings, there is not sufficient evidence to reject the null hypothesis in favour of hypothesis five.

Subproblem 6: Aptitude Effects and Expressed Attitude

Hypothesis six stated,

> There will be a significant aptitude-treatment effect with *HEM/CBIaudio* generally expressing less positive attitudes towards CBI Mathematics.

A two-factor ANOVA of the total percentage mean scores on the 42-item attitude questionnaire was conducted to test for main, aptitude and interaction effects. Results are shown in TABLE 15.

TABLE 15
Summary Table of Two-Factor Analysis of Variance
of Overall *Expressed Attitude* Towards CBI Mathematics

SOURCE	SUM OF SQUARES	DF	MEAN SQUARES	F	P
Treatment *CBIaudio/CBItext*	9.26	1	9.260	.10	.75
Ability *HEMS/LEMS*	90.43	1	90.43	1.00	.32
Ability X Treatment	44.43	1	44.43	2.49	.49
Error	6979.36	77	90.64		

Test results did not reveal significant main, aptitude or interaction effects. Additional t-tests for paired samples for both *HEMS* and *LEMS* were also conducted and yielded similar results. Based on these findings, one cannot support the research hypothesis that *HEMS/CBIaudio* express significantly different overall attitudes towards CBI Mathematics.

Within Treatment Effects, *Overall Expressed Attitude*. Two final comparisons of ANOVAs of mean total percentage scores on the 42-item attitude survey between *HEMS* and *LEMS* learners within *CBIaudio* and *CBItext* treatment groups, were completed in order to detect any significant difference in overall *expressed attitude* between the two aptitude subpopulations. Each of these are presented in turn.

TABLE 16 reveals that within *CBIaudio*, *LEMS*'s mean total percentage score of *expressed attitude* towards CBI Mathematics is significantly more positive than *HEMS* ($p \leq .05$).

In this case, there is sufficient evidence to reject the null hypothesis of no significant difference between aptitude groups. Within *CBIaudio*, the research hypothesis is supported. As hypothesized, *LEMS/CBIaudio* generally expressed significantly more positive attitudes towards CBI Mathematics than their *HEMS/CBIaudio* counterparts. The addition of a matched redundant digital audio component appears to have mildly polarized the overall *expressed attitude* of the two aptitude groups.

TABLE 16
Summary Table of Analysis of Variance on
HEMS/LEMS Overall *Expressed Attitude* towards CBI Mathematics
Within *CBIaudio* Treatment Group

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	542.28	542.28	5.15	.03
Within Groups	39	4105.48	105.27		
Total	40	4647.75			

GROUP	N	MEAN	SD	SE	MIN.	MAX.
HEMS	20	54.65	10.343	2.313	35.35	74.89
LEMS	21	61.93	10.18	2.22	36.74	81.40
Total	41	58.378	10.78	1.68		

On the other hand, TABLE 17 demonstrates that there is no significant differences in mean scores in the comparison group.

TABLE 17 reveales that within *CBItext*, no significant differences between students' mean percentage total score of *expressed attitude* towards CBI Mathematics was observed. The absence of a matched redundant digital audio component did not result in a significant differences in the overall *expressed attitude* scores of *HEMS* and *LEMS*.

TABLE 17
Summary Table of Analysis of Variance on
HEMS/LEMS Overall *Expressed Attitude* towards CBI Mathematics
Within *CBItext* Comparison Group

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	188.45	188.45	2.54	.12
Within Groups	39	2895.77	74.22		
Total	40	3084.21			

GROUP	N	MEAN	SD	SE	MIN.	MAX.
HEMS	20	55.51	9.19	2.05	42.80	76.28
LEMS	21	59.80	8.037	1.75	40.47	71.17
Total	41	57.71	8.78	1.37		

Additional Findings

Post hoc investigations included analysis of additional achievement, time related and attitude findings. Each of these are discussed in turn.

Additional Achievement Findings

Practice Exercise scores were automatically electronically captured in students' performance data files. A two-factor ANOVA was conducted to determine if the addition of matched redundant digital audio significantly impacted on short-term retention of mathematical concepts. Results detailed in APPENDIX 9 revealed that no significant differences in main, treatment or interaction effects with respect to *Practice Exercise scores* were observed. Although no significant findings were observed, the results were reported in this section because they are important in understanding the *Practice Exercise time* findings and implications discussed next.

Additional *Time* Related Findings

Post hoc investigations included an analysis of each of the three time related variables; *initial load time*, *total Practice Exercise time* and *total connect time*.

Initial Load time of the *CBIaudio/CBItext* files respectively, was not included in the computation of *time spent in learning*. This was done in an attempt to provide a more accurate measure of actual *time spent in learning* without the confounding effects of the lengthy wait-time for the *initial* audio file *load time*. The *initial load time* for *CBIaudio* and *CBItext* was analyzed using a two-factor ANOVA test. Findings are presented in APPENDIX 4.

Results revealed that *CBIaudio* and *CBItext* did differ significantly on the *initial load time* variable ($p \leq .05$). Sufficient evidence exists to reject the null hypothesis of equivalency of groups on this variable. As would intuitively be expected, it did take a significantly longer time to load the initial *CBIaudio* files (compared with *CBItext* files).

Practice Exercise Time was the second *time* related variable examined. As described in Chapter III, subjects in both treatment groups completed the *Practical Exercises* without the addition of an audio component. Results of the two-factor ANOVA tests on *Practice Exercise* times are tabled in APPENDIX 6.

Results indicate that there is a significant difference in average mean time spent on lesson *Practice Exercises* between *CBIaudio* and *CBItext* ($p<.05$). There is sufficient evidence to reject the null hypothesis of equivalency of groups on this variable. *CBIaudio* (with a mean of 2115 seconds) spent significantly smaller amounts of time than *CBItext* (with a mean of 2663 seconds) on the lesson *Practice Exercises* after having been previously exposed to matched redundant audio in combination with text screens throughout the lessons (dual-channel learning).

Further analysis of aptitude groups revealed that although both *CBIaudio* and *CBItext* completed identical *Practice Exercises* (ie. both without audio), it did take a significantly shorter time for *HEMS* in the *CBIaudio* treatment condition to work through and complete the three Math*Tech 10* Unit 3 Topic 1 *Practice Exercises* following each lesson. This effect did not occur for the *LEMS/CBIaudio* group. It appears that the HEMS's short-term retention of the mathematical concepts introduced in dual-channel mode may affect the efficiency of their test taking abilities. Further research into this topic may be worthy of consideration.

Total Connect Time. Results in APPENDIX 7 indicate that there is no significant difference in average mean *total connect time* between *CBIaudio* and *CBItext*. There is not sufficient evidence to reject the null hypothesis of equivalency of groups on this variable. Notwithstanding the differences outlined in the discussions on the other *time* related variables, both *CBIaudio/CBItext* spent approximately the same overall *total connect time* completing the three Math*Tech 10* Unit3 Topic 1 modules.

Further analysis revealed that *HEMS* and *LEMS* differed significantly on the amount of *total connect time* within the *CBItext* comparison condition ($p<.05$).

Therefore, there is sufficient evidence to reject the null hypothesis of equivalency of groups on this variable. As would be expected, it did take a significantly longer mean time for the *LEMS* students to complete the three *CBItext* Math*Tech 10* Unit 3 Topic 1 modules in their entirety.

A level three analysis revealed that *LEMS* did not differ significantly on the amount of *total connect time* (compared with *HEMS*) within the *CBIaudio* treatment condition. There is not sufficient evidence to reject the null hypothesis of equivalency of aptitude groups on this variable within the treatment group. Unlike the *CBItext* comparison group, it did not take a significantly longer mean time for *LEMS* to complete the three *CBIaudio* Math*Tech 10* Unit 3 Topic 1 modules as compared with their *HEMS* counterparts.

Additional Attitude Findings

A post hoc analysis of subjects' mean responses to each of the attitude questionnaire items at three levels of analysis was conducted. One-way analysis of variance yielded significant values for 13 of the 42 questionnaire items. Although findings for any one item in isolation can not be deemed significant, it is interesting to note the pattern that emerges. For the sake of brevity, the test findings and interpretations are summarized in APPENDIX 12.

CHAPTER V: DISCUSSIONS AND RECOMMENDATIONS

The purpose of this study was to determine the relative impact of dual versus single-channel CBI presentation on the learning of Math*Tech 10* Unit 3 Topic 1. Specifically, the study attempted to investigate the effects of supplementing Computer Based Instruction (CBI) with redundant (matched, full-text) digital audio. Investigations included significant differences in student *achievement in*, *time spent in learning*, and *expressed attitude* towards CBI Mathematics at the tenth grade level. Secondary investigations were concerned with the effects of student aptitude in the two treatment conditions on the three aforementioned variables.

Chapter V begins with a discussion of the findings of the study as they relate to each of the six hypotheses respectively. Influences that may have affected the subjects' performances in each of the areas are proposed. Based on the implications drawn from the research findings, guidelines and recommendations for future audio research studies and/or audio instructional designs are offered in each of the three sections respectively. Section IV reviews additional findings. Chapter V continues with a brief summary of the recommendations for future studies and concludes with a summary statement. Some final thoughts are presented at the end of Chapter V.

Section I
Achievement

The two achievement hypotheses stated:

H1) There will be no significant differences between *CBIaudio* and *CBItext* on achievement scores on Math*Tech 10* Unit 3 Topic 1.

H2) There will be a significant aptitude-treatment effect on achievement in favour of *LEMS / CBIaudio*.

Achievement Findings

H1) The corresponding null hypothesis was retained indicating that there were no significant differences among the main treatment groups (*CBIaudio / CBItext*) in achievement gain.

H2) The null hypothesis was retained indicating that there was not a significant aptitude-treatment effect on achievement in favour of *LEMS / CBIaudio*.

Discussion and Interpretation of Achievement Findings

Results indicated that Math*Tech 10* Unit 3 Topic 1 with *CBIaudio* and *CBItext* without redundant audio proved equally effective modes of lesson delivery from an achievement gains perspective. These findings are consistent with the conclusions reached by Barron in her 1991 study which stated that "no treatment group demonstrated superior achievement gains over the other group" (p. 72).

In keeping with the literature reviewed and as predicted in hypothesis one, to date there appears to be little empirical data to substantiate that learner effectiveness is enhanced by combining redundant audio with text lesson instructions. Secondly, although the audio study attempted to detect subtle differences in individual learners as suggested by Unwin (1988), no evidence was observed to support hypothesis two that *LEMS's* achievement scores may significantly increase as a result of assignment to *CBIaudio*.

Five plausible explanations present themselves as to why the level of achievement was the same regardless of whether one or two channels of communication were programmed into the module.

First, the length of exposure to lessons with (*CBIaudio*) and without audio (*CBItext*) may not have been adequate to produce observable differences in a achievement gains. Although this study involved a significantly longer CBI tutorial time than Barron's 1991 study, the tutorial may still not have been long enough to elicit significant achievement effects.

Second, the selected sample group of Mathematics 10 learners in this study may not have had sufficiently deficit levels of related skills and/or the essential learning characteristics (for example, significantly reduced levels of reading proficiency or low levels of prior mathematical knowledge) necessary to benefit from the addition of redundant audio to a CBI Mathematics module. If this study were to be repeated with adult distance education learners or a group of Mathematics 10 learners that have lower than average reading levels or even lower EMS, a significant difference in achievement gains may be observed.

Pre-screening subjects on the basis of reading levels and/or prior mathematical knowledge (EMS) in order to assign them to treatment conditions is highly recommended as a means of controlling for possible confounding effects in future studies. Efforts could also be made to determine if other deficit levels of essential skills and/or learning characteristics are correlated with achievement gains with dual-channel CBI Mathematics learning presentations.

Third, in keeping with the preceding line of reasoning, the suitability of adding redundant audio to Math*Tech 10* (versus CBI Mathematics 13 or another mathematics course) may have impacted on the achievement findings themselves. That is, Mathematics 13 students may, on average, have more difficulty learning from a print-text environment and may respond in a more significant fashion to the addition of redundant digital audio. Future studies may wish to repeat this type of study with other courses designed for students with lower entry achievement scores.

Fourth, test-channel bias (as identified by Hartman (1961b), in favour of *CBItext* comparison group may have occurred. As stated in the delimitations section of the study, due to the parameters within which the present audio study was required to function, redundant audio was not added to the *Practice Exercises* for *CBIaudio*. The presence of test-channel bias in favour of *CBItext* may have been sufficient to mask any differential effect that might have been present in favour of *CBIaudio*. Future replications of the audio study, with redundant audio added to the *Practice Exercise* portion of the module, might help control for the confounding effects of test-channel bias.

Fifth, as Barron concluded in her 1991 study, the achievement findings of this study could be seen to provide support to Broadbent's single channel processing theory as outlined in Chapter II. If, as Broadbent postulated, humans only have one channel of communication to the brain, then the addition of completely redundant audio would not result in significant differences in achievement gain. It is this researcher's opinion, however, that this study does not necessarily provide support for this theory. As will be discussed in the additional findings section, *HEMS/CBIaudio*'s short-term retention of Unit 3 Topic 1 concepts appeared to be positively effected by the dual channel presentation in that differential times spent on *Practice Exercises* by *CBIaudio/CBItext* subjects were noted. In effect, *HEMS/CBIaudio* were more efficient.

Hsia's (1968a) capacity limit theorem of the central nervous system offers a slightly different explanation of the achievement results. Hsia's theory might explain that the audio-visual presentation was not a more efficient method of presenting communication materials due to the fact that the combined amount of information of audio and visual stimuli exceeded the upper limit of the central nervous system capacity such that selection processes and interference took place. In that this study did not detect significant achievement gains in favour of one condition as opposed to the other (either *CBIaudio / CBItext*), no empirical evidence to either disprove or substantiate Hsia's theory has resulted. Future studies will have to grapple with this unresolved controversy.

After reviewing the literature and the results of this study, it is this author's opinion that Hsia's theory is relatively more congruent with much of the earlier audio research work and with Barron's findings and suggestions themselves. In Barron's 1991 study, the *Partial-text* treatment group received the original lesson information in an audio format combined with a more compressed bulleted text screen. The *Partial-text* treatment group's achievement scores were not significantly different from the other two treatment conditions (*Full-text / Audio* and *Text-only*). Although the reported results were not significantly higher, they were also not significantly lower. Barron argued that since the addition of redundant audio did not negatively impact on learner achievement, redundant audio could be used to replace busy text screens (Screen Real Estate). Future studies on CBI Mathematics may wish to further investigate this possibility.

Informal comments made by teachers and subjects in this audio study revealed that they believed that the addition of audio would be more useful and effective if it supplemented instructions or offered new information which was not already present in the text-screen. Future audio studies may also wish to explore the addition of *related* audio to Math*Tech 10* to investigate if its inclusion increases learner achievement or interferes with the learning performance.

Section II
Time Spent In Learning

The two *time spent in learning* research hypotheses stated:

H3) There will be no significant differences between *CBIaudio* and *CBItext* on *time spent in learning* Math*Tech 10* Unit 3 Topic 1.

H4) There will be significant differences between the aptitude-treatment groups (*HEMS* X *CBIaudio/CBItext* and *LEMS* X *CBIaudio/CBItext*) on *time spent in learning*.

Time Spent in Learning Findings

H3) The null hypothesis was retained indicating that there were no significant differences among the main treatment groups (*CBIaudio/CBItext*) in *time spent in learning*.

H4) The null hypothesis was rejected indicating that there were significant differences between one of the two aptitude groups in the two treatment conditions in *time spent in learning*.

Discussion of *Time Spent in Learning* Findings

Main Effects, Discussion. Results tabled in Chapter IV indicated that mean *time spent in learning* Math*Tech 10* Unit 3 Topic 1 as hypothesized, was not significantly different between main treatment groups. This finding supports Suppes earlier work (1961-81) on university students preferences for computer-assisted instruction with audio in which he reported that treatment groups did not significantly differ on *time spent in* *learning* with and without (synthetic computerized speech) audio.

At first glance, these same findings appear to contradict Barron's more recent study results (1991). Barron reported that she observed a significant difference in mean time required to complete the tutorial among the three treatment groups with the *Text-only version* requiring the least time on task. How can the apparent differences in the findings be explained? Two plausible explanations are offered.

First, the observed differences could be due to the way in which the two studies operationally defined *time* as variable. Barron's inclusion of the *initial load time* and time spent on the follow up *post-test quiz* in her calculations of *time* could account for the differences in results. Barron did not attempt to differentiate between *initial load time*, *time spent in learning*, *Practice Exercise* time and *total connect* time as was done in this current study. Failure to use the terms in a consistent and comparable manner is often a common problem in audio research as pointed out in Chapter II.

Second, the difference in the findings, may also be due to the very short overall tutorial time (18 minutes) that Barron's study incorporated. This study included a longer tutorial time (120 minutes) as suggested by Barron in the recommendation section of her study. Perhaps *time spent in learning* differences are so subtle that a short tutorial time does not elicit, detect and/ or reveal them.

Aptitude Effects, Discussion. A significant difference in *time spent in learning* between *HEMS/CBIaudio* and *HEMS/CBItext* was observed. Sufficient evidence was provided to reject the null hypothesis of no significant difference ($p \leq .04$). This effect was not observed between comparisons of *time spent in learning* by *LEMS/CBIaudio* and *LEMS CBItext* ($p \leq .96$).

One can deduce that the main treatment effect observed was not due to an overall global difference between *CBIaudio* and *CBItext* but rather to *LEMS'* differences in responses to the two treatment conditions. In other words, *LEMS* spent almost identical mean average time in learning Lessons 1, 2 and 3 regardless of their assignment to *CBIaudio* or *CBItext* (*CBIaudio* = 4703 seconds / *CBItext* = 4725 seconds). *HEMS*, however, differed significantly in mean *time spent in learning* under the two treatment conditions, with *HEMS/CBIaudio* taking a significantly longer mean time (4125 seconds) compared to *HEMS/CBItext* (3371 seconds).

Implications, Time Spent in Learning. What are the implications of this finding for education learning theorists and instructional designers? How might they explain and interpret the studies' findings with respect to *time spent in learning*? Possible speculations concerning different learning strategies and approaches employed by *HEMS* and *LEMS* students under the two treatment conditions follow.

As was suggested by Kozma in the literature reviewed, individual students vary widely in the amount of time they require to read, comprehend and absorb new material depending on their level of prior knowledge in that particular subject area. Burk's (1972) research found that "average readers may be able to read faster than the average speaker talks" (p. 41). Unwin (1988) also reported that "most persons can listen and comprehend at rates much higher than the average speaking rate." (p. 36).

The aforementioned researchers' findings would support the speculation that subjects in *HEMS/CBIaudio* were probably capable of reading and comprehending the lesson material in a text format at a faster pace than it could be presented in a combined text-audio format given the current limitations of the technology. In essence, *HEMS/CBIaudio* were held back or slowed down by the exposure to *CBIaudio* whereas *LEMS/CBIaudio* were not. In fact, *LEMS* lack of differential *time spent in learning* seems to support Eraut s (1989) claim that "... slower learners (can) require five to six times as long as faster students to master a set of learning materials" (p. 400).

Although this apparent forced increase in *time spent in learning* did not adversely affect *HEMS/CBIaudio's* achievement scores, it did appear to correlate with higher levels of frustration as reflected in *HEMS/CBIaudio's* more negative scores on *expressed attitude* towards CBI Mathematics.

Based on the preceding findings, CBI Mathematics instructional designers targeting a wide and potentially diverse high school audience, might do well to heed Eraut's (1989) suggestion that "... providing for individualization in rate of instruction seems advisable, especially when the learner population is heterogenous" (p. 400). Given that *HEMS* and *LEMS* learners appear to have diverse reactions to the dual-channel CBI presentation, it also provides support to Suppes' (1981) suggestion that "Whenever possible, it seems highly desirable that both modalities be offered, with free choice of their use left to the individual student" (p. 429).

Instructional designers, on the other hand, whose mandate is to develop CBI Mathematics materials for gifted learners exclusively (or subjects with a strong background knowledge of the subject area), would be well advised to consider if the inclusion of redundant audio would be worth the extra development time, cost and energy given the results of studies to date. However, if they concluded that the audio component is a viable option, they might consider building in an option which would allow gifted subjects to turn off the audio component if they so desired. That is, if a student had reached a specified level of achievement on prior units, an option button to select/deselect audio could be made available.

Research suggests that *LEMS* may not be as capable as their *HEMS* counterparts of deciding whether or not they would benefit from the addition of audio. Despite the additional development time, cost and effort, there appears to be more reasons why instructional designers charged with developing suitable CBI mathematical materials for average or below average students exclusively, may elect to add dual-channel learning modules. Likewise, CBI courses designed for learners that have had more difficulty learning mathematical concepts either due to poor mathematical aptitude and/or poor reading comprehension skills may also benefit from the inclusion of redundant audio information.

Further research is needed to determine if the differences detected in this CBI audio study, are attributable solely to the subjects' weak prior mathematical experiences (LEMS) or due to other variables such as weaker reading comprehension levels which may affect their ability to learn new mathematics concepts. CBI instructional designers developing materials for subjects with lower entry mathematics scores, may wish to build an option for the teacher to select/deselect the audio component for these students.

Since this study did not observe any related achievement score gains due to treatment exposure, the following questions remain for future research. Does the addition of redundant audio help a *LEMS* student:

1) attend better to important information by the instructors' tone or emphasis on certain key words as suggested by Hartman (1961)?
2) comprehend the new material easier because the subjects are not as likely to assume they know the material and skim ahead? (Earlier studies have demonstrated that students do not always accurately judge when they have spent enough time on learning a new concept.)

Section III
Attitude Towards CBI Mathematics

The lack of achievement differential discussed in the first part of Chapter V, may indicate to some instructional designers and educational learning theorists, that the additional time, effort and cost of adding audio may not be warranted. However, another variable, *expressed attitude* towards CBI Mathematics, could also potentially prove crucial in any attempt to fully investigate, understand, and detect the importance and value of adding audio to CBI Mathematics modules. The fifth and sixth subproblems attempted to determine if the addition of audio produced observable and positive effects on learner attitude which could also justify the added time, cost and effort.

Expressed Attitude Findings

H5) The null hypothesis was retained indicating that there was no evidence of significant differences among the main treatment groups *CBIaudio/CBItext* in overall percentage scores of *expressed attitude* towards CBI Mathematics.

H6) The null hypothesis was rejected indicating that there was evidence of significant differences between *HEMS* and *LEMS* within the two treatment conditions in overall percentage scores of *expressed attitude* towards CBI Mathematics. *LEMS/CBIaudio* generally expressed relatively more positive attitudes towards CBI Mathematics than their three other counterparts.

Discussion *of Expressed Attitude* Findings

Significant differences in *expressed attitude* towards CBI Mathematics by *CBIaudio* and *CBItext* observed are discussed and interpreted in the following section. Implications of the findings follow. The section ends with general comments about the relevance of including *expressed attitude* towards CBI Mathematics as a variable in future CBI audio research studies at the high school level.

No significant differences were observed between main and aptitude-treatment groups on this variable at the first two levels of analysis in the various tests conducted. Two separate ANOVA tests at the third level of analysis revealed some significant findings.

Within Treatment Effects, Discussion. A Level 3 analysis to determine any variance in effects experienced by either *HEMS* and/or *LEMS* learners within treatments (*CBIaudio* or *CBItext*) was conducted to detect if significant differences in *expressed attitude* towards CBI Mathematics occurred.

Significant differences by *HEMS* and *LEMS* within *CBIaudio* with respect to overall *expressed attitude* towards CBI Mathematics were observed ($p \leq .02$ See: APPENDIX 10). The mean overall percentage scores of *expressed attitude* towards CBI Mathematics varied significantly within *CBIaudio* with *LEMS* expressing a significantly more positive mean score of 61.9% compared with *HEMS*'s 54.6%. The same significant variation was not observed *within* the comparison group (*CBItext*); *LEMS* with 59.8% and *HEMS* with 55.5%.

This analysis seems to verify that the addition of redundant audio is perceived by *LEMS* in a more positive manner as compared with their *HEMS* counterparts. Although the same directional effects did occur within the comparison group (*CBItext*), they were not at sufficient levels to be considered significant. This finding once again lends support to the study's conclusion that the addition of matched redundant digital audio to text-based Math*Tech 10* Unit 3 Topic 1 did have a significant effect on HEMS' and LEMS' *expressed attitude* towards CBI Mathematics.

Additional Findings

Additional Time Related Findings

Results with respect to each of the three time-related variables are presented along with implications for future studies of the respective findings.

Initial Load Time. As would intuitively be expected given the parameters under which the audio study was conducted, the *initial load time* for *CBIaudio* was significantly longer than the *initial load time* for *CBItext* ($p \leq .00$). This analysis confirms that, as expected, *initial load time* is a function of the computers' hard drive speed and the size of the file being loaded into memory as opposed to being a function of the specific user and their individual abilities.

As file compression-decompression technology improves and as students have access to the newer technology either through distance education programs or through new home information highway networks, a reduction of the *initial* audio *file load time* (and the audio run file time) should be reduced to the point where it will no longer be considered a significant confounding variable. Until such time, however, digital audio studies will need to continue to make attempts to ensure that the time required to load and run large audio files, does not add to the frustration of the subject in such a way that it has a detrimental and confounding effect on the results or the subjects' attitudes.

As discussed previously in this chapter, it remains important to isolate this variable in order to get a clearer picture of the effects of audio on actual *time spent in learning* as opposed to measuring *time spent in waiting* for access to audio files.

Practice Exercise Time. Some unexpected and interesting results were encountered with respect to the second time-related variable, *Practice Exercise time (See: APPENDIX 5).* Although subjects in both treatment conditions completed the *Practice Exercise* portions of the Math*Tech 10* Unit 3 Topic 1 Lessons 1, 2 and 3 module without the addition of redundant audio instructions, *CBIaudio* completed the three Practice Exercises in a significantly shorter time than *CBItext* ($p \leq .01$).

Level 2 analysis reported in APPENDIX 5 revealed that mean *Practice Exercises time* was significantly less for *HEMS/CBIaudio* ($p \leq .02$). There appears to be a significant carry over effect for *HEMS* which impacts on *Practice Exercise* time when the practice exercises are completed immediately following treatment exposure to dual-channel information. That is, although *HEMS/CBIaudio* subjects did not score significantly higher on the *Practice Exercises* as compared to *HEMS/CBI text,* they were able to achieve comparable results in significantly less time. The same directional effect seems to have occurred for *LEMS* learners in the *CBIaudio* treatment group, however the effect did not register in the significant range. That is, *LEMS/CBIaudio* completed the *Practice Exercises* in less time (but not significantly less) with the same degree of success, as their *LEMS/CBItext* counterparts.

This finding seems to indicate that in terms of short-term retention of Mathematics 10 concepts, dual-channel presentation appears to have an impact on the ease at which materials are recalled and applied in a problem-solving test situation. Variances in individual subject's time spent on completing the *Multiple Choice Final Exam* was not recorded. It was therefore, not possible to determine if the same directional effect occurred in tests measuring long-term retention of the selected Mathematics 10 concepts. Future studies may wish to investigate this phenomenon.

If the same achievement results are attainable with less practice exercise test-taking time, total time needed to complete CBI Mathematics courses could be reduced saving student laboratory hours. The implications of such a finding might also be of interest to educational learning theorists who have yet to fully explore and understand the educational benefits of the use of dual versus single channel communication technologies.

Total Connect Time. Although significant differences were found between *initial load time* and *Practice Exercise time* for *CBIaudio/CBItext*, significant differences between the treatment groups were not observed with respect to the third variable, *total connect time* ($p \leq .83$). (See: APPENDIX 7). That is, the two treatment groups, spent equivalent mean times completing Math*Tech 10* Unit 1, Topic 1, Lessons 1, 2 and 3 in its entirety. As discussed in the earlier *time spent in learning* section of this chapter, this finding appears to contradict Barron's (1991) earlier finding that subjects in the combined audio/text treatment condition took significantly longer to complete the tutorial as compared to the other two treatment conditions. These results are in keeping with Suppes earlier work (1961-1981) and add support to his findings. For possible explanations of these differences, please refer to *time spent in learning*, discussions section earlier in this chapter.

Implications for future instructional designers. One concern raised about adding audio to current CBI courses is the fear that the large audio file load and access time would add significant time needed to complete any given course. In that this did not prove to be the case in this study, current CBI designers may feel more at ease with adding audio.

Additional Attitude Findings

Main effects. Discussion. As outlined earlier in Chapter IV, no significant difference in overall mean scores of *expressed attitude* towards CBI Mathematics was observed between *CBIaudio/CBItext*. However, one questionnaire response did evoke a significantly different response from the two main treatment conditions. It's findings are of practical importance with respect to hypothesis five. The questionnaire item was:

Question 5: "I felt as if someone were engaged in a conversation with me." Subjects in *CBIaudio* answered this question in a significantly more positive manner ($p \leq .05$). The addition of redundant audio to text-based Math*Tech 10* Unit 3 Topic 1, Lessons 1, 2, and 3, appeared to make subjects in the treatment condition more likely to feel like someone was engaged in a conversation with them.

Although one out of forty-two responses may not necessarily be statistically significant, it is interesting to note the pattern that emerges. The results could be interpreted to mean that interaction with the technology in this study was perceived as more personal and more human-like by subjects assigned to *CBIaudio*. Even though identical lesson text and feedback messages appeared on screen for *CBItext*, comparison subjects did not elect to describe the experience in as positive a manner as their treatment counterparts.

Barron (1991), in her analysis of the post-treatment perception questionnaire, found a significant difference in responses to one questionnaire item, namely, "... computer programs make me nervous and uncomfortable" (p.75). She observed that the addition of redundant audio to *Full-text* or *Partial-text* (bulleted) university level tutorials, appeared to make subjects less likely to agree with the statement as compared to subjects in the *Text-only* condition. Barron also concluded that the addition of audio for the two other treatments *(Full-text* and *Partial-text)* may have had an effect on lowering students' anxiety levels (p.75).

If the addition of redundant audio to CBI Mathematics modules encourages students to attribute more human like characteristics to the technology (or the CBI program itself), it could ultimately prove to be a contributing factor in increasing the comfort level and/or lowering the anxiety level of the learner. Future studies will be needed to determine if this is the case.

If the preceding proves correct, the question then becomes whether being more comfortable as a learner (ie. having lower anxiety levels) necessarily results in the attainment of higher achievement. If a correlation does not exist, as appears to be the case in this particular study, then instructional designers will have to decide whether the added comfort is worth the extra time, development cost and increased need for file space and for whom and under what conditions.

Aptitude Effects, Discussion. The second level of analysis was conducted primarily to address Hypothesis 6. On t-tests for paired samples on the overall mean scores of *expressed attitude* towards CBI Mathematics, no significant differences in responses were observed between *HEMS* X *CBIaudio/CBItext* and *LEMS* X *CBIaudio/CBItext*. At the second level of analysis, two questionnaire items out of forty-two, did evoke significant differences between the two aptitude groups' mean score responses. These are reviewed and discussed next. Implications of each are offered in turn.

Question 33: "I felt I could work at my own pace." *HEMS / CBIaudio* learners answered this question in a significantly more negative direction than those in *CBItext* ($p \leq .01$). The sixth hypothesis, which suggested that *HEMS* students in *CBIaudio*, will generally express significantly less positive attitudes towards CBI Mathematics, was therefore supported with respect to this questionnaire item.

One could interpret these findings to mean that *HEMS* students (ie. students that were either relatively more knowledgable regarding basic mathematics concepts before the start of this study and/or students that have a better than average reading proficiency), found the presence of audio in the lesson portion of the CBI module to be interfering in the sense that it impacted on their perceived freedom to work at their own pace. It is interesting to note that *LEMS* students in both treatment conditions on the other hand, did not express significantly different responses to this question.

An examination of the actual recorded *time spent in learning* for the *HEMS* in *CBIaudio* and *CBItext* respectively, reveals that a real (not just perceived) and significant discrepancy in times for the two groups was observed. Therefore, it seems reasonable to conclude that *HEMS* probably did, in fact, experience a slowing down due to the presence of the audio in the lesson portion of the CBI Mathematics 10 module.

However, it should be noted that *HEMS / CBIaudio* subjects were probably also not aware that they did make up for this lost time. *HEMS / CBIaudio* subjects on average actually completed the *Practical Exercises* in a significantly shorter time as compared with *CBItext*. This reversal of effects also explains why *HEMS/CBIaudio's* overall *total connect time* was not significantly different from their counterparts (*HEMS / CBItext*) as a result of assignment to treatment conditions.

The preceding findings are in keeping with Suppes' earlier work (1961-1981) in which he found that university students perceived the *Audio/Full-text* university course tutorial as taking longer even though in real time the *total connect times* in both treatment groups were almost identical. Suppes, like Barron (1991), did not break down the *time* variable in his studies into subcomponents for analysis. It therefore, is not possible to determine if a similar effect was also present in his studies that would account for the differences in subjects' expressed perceptions of time and actual time recordings. Future audio studies might be cautioned to pay more strict attention to the operational definition of *time* so that more precise understandings of the role of *time* as a variable may be attainable.

Question 26: "I knew whether I was right or wrong before I was told." The second questionnaire item which evoked significantly different responses from the aptitude groups was Question 26. In this case, ***LEMS/ CBIaudio*** were significantly more likely to answer "Some of the time" as opposed to "Seldom" or "Never" to Question 26 ($p \leq .05$). Interestingly enough, ***HEMS*** in both treatment conditions, who probably had more reason to believe they knew whether they were right or wrong before feedback was given, did not show any significant differences in response to the same question. Therefore, support was given to the acceptance of hypothesis six.

One could speculate that ***LEMS/CBItext*** may have found it easier to overlook and ignore the text feedback as it appeared on screen. By voicing the feedback, more attention may have been drawn to it. Lab observations noted that some of the subjects described the feedback as outdated (ie. "Right on!") and difficult to interpret in intent in some cases.

It was noted by the researcher that some subjects in *CBIaudio* seemed genuinely disappointed that the feedback was not more varied and personal.

The *CBIaudio* feedback was identical in content to the *CBItext* feedback by design in that it was to be redundant and was to match the original text-screen version. All feedback was randomly generated from a data base pool of positive and negative statements from the original Math*Tech 10* module. Perhaps because the voiced feedback was more human-like, higher expectations about the content of the feedback were also generated. When these expectations were not met, perhaps it evoked the observed response to this questionnaire item. Future studies may wish to pursue answers to the questions this finding raised.

Within effects, Discussion. The third level of analysis was conducted primarily to address Hypothesis 6. Findings with respect to eight questionnaire items were presented in APPENDIX 12.

In summary, the eight questionnaire item analysis revealed that the *HEMS/CBIaudio's* and *LEMS/CBIaudio's* average weighted scores differed significantly. The null hypothesis of no significant differences in aptitude-treatment group's *expressed attitude* towards CBI Mathematics was rejected with respect to these eight questionnaire items.

Since similar effects did not occur within *CBItext*, these series of findings lend further support to the hypothesis that significant differences in *expressed attitude* towards CBI Mathematics will be observed between *HEMS X CBIaudio/CBItext and LEMS X CBIaudio/CBItext* due to treatment effects.

The general tone of the findings seem to be in keeping with several of the earlier findings reported in the literature. Suppes (1961-1981) earlier work particularity stressed that a diverse range of individual responses to audio were expected. Bangert-Downs (1985) studies at the secondary level found that students' attitudes were generally positive towards CBI. The findings outlined in the preceding are generally consistent with these works.

This studies results with respect to aptitude groups *expressed attitude* did not support Rosen, Sears & Weil's (1987) earlier findings suggested that students who expected poor grades had greater discomfort using a computer than those who expected higher grades. Generally, the *LEMS* students in the study expressed more positive attitudes towards CBI Mathematics than their *HEMS* counterparts in both treatment conditions. Many LEMS informally expressed their pleasure with the success they encountered as they completed the first lesson module. They commented on how nice it felt to work through a unit and get the answers right for a change.

In light of this relative positive response in terms of expressed attitude of *LEMS* subjects, it might be time to reconsider many schools unofficial policy of letting the gifted have first access to computers. Perhaps this policy unfairly targets the wrong aptitude group at the expense of those learners who might truly benefit from access to newer technology.

Recommendations

Specific implications, recommendations, and questions requiring further study were offered in Section I, II and III of Chapter V with respect to each of the six subproblems and related hypotheses.

In light of the preceding findings, designers of CBI instructional materials for high school students with prior above average mathematical subject knowledge (HEMS) and/or above average reading proficiencies, may wish to weigh off the added cost, time and effort of adding redundant digital audio, against the current lack of studies confirming the benefits of adding audio for HEMS in terms of achievement gains and attitude gains.

Learning theorists concerned with the development of mathematical materials for high school students with less than average prior mathematical subject knowledge (*LEMS*) and/or below average reading proficiencies, may wish to further investigate how the addition of audio effects *LEMS* in terms of their achievement, time needed for learning and for test taking, and in their overall attitude towards learning with CBI technologies. To date little is understood regarding the complex variables that are significant in terms of facilitating maximum learning benefits for *LEMS*.

Designers of mathematical materials for high school students with an unknown and/or wide range of diverse learning characteristics and reading proficiencies, may wish to include as many options as possible for students to select/ turn off and on and repeat audio in its many formats and combinations until further empirical evidence regarding its impact on learner effectiveness is available.

Chapter Summary

This study was conducted in the tradition of dual versus single channel research, to investigate the effectiveness of redundant audio in Computer-Based instruction at the high school level. Mathematics 10 subjects at a local high school were assigned treatment conditions by stratified match pairs within three existing classes. The treatment consisted of the exposure to an identical Math*Tech 10* module with (*CBIaudio*) and without audio (*CBItext*) in the lesson section of the module by subjects with a full range of prior mathematical aptitude (*HEMS / LEMS*).

Results of the study indicated that assignment to the two CBI delivery modes (*CBIaudio / CBItext*) did not have a significant effect on the overall comprehension and learning mastery of the related mathematics material. Differential carryover effects occurred in terms of the time needed to demonstrate understanding of concepts in the practical follow-up exercises with the same level of achievement results for the *HEMS* aptitude group. Perhaps due to better short-term retention of mathematical concepts as a result of exposure to dual channel lesson presentations, *HEMS* subjects in the *CBIaudio* treatment condition were able to complete the follow-up quizzes in a significantly shorter time frame without adversely affecting achievement level results.

With respect to *time spent in learning* findings, *LEMS* subjects in both treatment groups completed the module in approximately the same time. *HEMS* subjects however, did not spend equivalent time in learning, with *HEMS/CBIaudio* subjects appearing to be forced by the presence of the redundant audio itself, to spend significantly longer times in lesson learning than their comparison group counterpart. Although differences in *initial load time,* and time spent on the *Practice Exercises* (Quiz 1, 2 and 3) were noted, the two effects seemed to counter balance each other. Therefore significant overall *total connect time* differences were not observed between the two main treatment groups.

Regardless of experimental treatment, subjects generally rated their perceptions of the CBI Mathematics as positive. Although no significant differences in *expressed attitude* towards CBI Mathematics were observed between main treatment groups *(CBIaudio/CBItext)* evidence of practical differences between aptitude groups were observed. *HEMS* subjects perceived the presence of the redundant audio as more interfering and less positive, whereas *LEMS* subjects found it more helpful and generally more comforted by the presence of the audio.

The findings of this study should be generalizable to a wide-cross section of Alberta High school mathematics students with a wide range of mathematical abilities who are studying with the help of CBI delivery systems.

The findings of this study may help to provide guidelines for the development of future CBI programs and other multimedia applications. Chapter V identified various areas that may be worthy of future study and investigation, and suggested several implications for instructional designers.

Some Final Thoughts

The multichannel communication controversy remains unresolved and controversial to date. Many areas besides education, including the field of cognitive science and neuropsychology, continue multichannel learning research in an attempt to unravel the mysteries of how humans learn, recall, access and process information about ourselves and our world. Will the new computer-based technologies reveal new theories about learning channels or will man's way of attending to and processing information be radically changed due to the introduction of the technology itself?

There is a danger when the search for the "newest" and "latest" technologies to "do" the task and the subsequent flurry of activity on "when and where to" use the technology, seems to drive the "research", rather than the development of the "technologies" being "driven" by empirical findings and sound educational/instructional principles. It is this researcher's position that educational research studies investigating all facets of audio integration ("how to", "when to" and "why to") have a valid place in and contribute to the knowledge base of the field of voice/speech digital audio and should be equally encouraged in future studies.

Darlene Rehaag
Spring, 1994

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APPENDIX 1

Letter of Consent Form

University of Alberta
Department of Adult, Career and Technology
Thesis Title: Computer Based Instruction and Digital Audio

Consent Form

Having been invited by Darlene Rehaag, a graduate student in the Department of Adult, Career and Technology, to be in a research study, I understand that:

- This study looks into instructional design, student learning characteristics, learning modalities and success in learning Mathematics 10 by Computer-Based Instruction.
- This study involves only my Mathematics 10 course.
- The research data collected as a part of this study will not affect my mark in Mathematics 10.
- The researcher will have access to my final Grade 9 Mathematics marks and end of Unit 3 Mathematics 10 CBI test scores.
- All data regarding my progress in Mathematics 10 will be private.
- On all records regarding my progress in Mathematics 10, I will be known by an identification number, and only the researcher will have access to the master list matching names and code numbers.
- This study will be carried out in the month of October, 1993 or whenever my class begins Mathematics 10 Unit 3: Equalities and Inequalities.
- My being in this study is completely my choice. I may refuse to take part and/or opt out of the study at any time. Electing to do so will not effect my Mathematics 10 mark.
- I may express any concerns that I might have about the study to my teacher, the researcher (Darlene Rehaag, 458-9319), or the supervisor of this study (Dr. M. Szabo, Professor in the Department of Adult, Career and Technology, 492-0715).
- To maintain privacy, my name will not be in any report or thesis.
- The thesis this study leads to will be available for examination at the University of Alberta Library.

On the basis of these understandings I agree to take part.

Student Name	**Parent/Guardian Name**
Date	**Date**

APPENDIX 2

MATH 10 UNIT 3 TOPIC 1 QUIZ
SOLVING AND VERIFYING LINEAR EQUATIONS

NAME:____________________________

CLASS:____________________________

Multiple Choice: Circle the correct answer. (You may use the space beside the question as a workspace to show your work if you wish).

1. The length of a rectangular room is 2 m greater than 3 times the width. If w represents the width of the room in meters, then the length is:

    a. 3(w + 2) m
    b. (3w + 2) m
    c. (w + 6) m
    d. 3(w - 2) m
    e. (3w - 2) m

2. Bob has twice as many dimes as Hank. If x represents the number of dimes Hank has, then which expression would represent the dollar value of Bob's dimes?

    a. $2x
    b. $0.2x
    c. $20x
    d. $0.02x
    e. $200x

3. Cara is trying to find three consecutive integers whose sum is 132. If the smallest of the integers is x, what expression would represent the largest integer?

a. x + 3
b. 3x
c. x + 1
d. x + 2
e. x - 3

4. If x represents some real number, then 2x - 5 would represent:

a. a number doubled and then reduced by 5
b. reducing 5 by a number and then doubling the result
c. twice the difference of a number and 5
d. a number doubled and then increased by 5
e. the difference of 5 and a number doubled

5. Jeans were on sale for $29.99 a pair. Bob spent $179.94 on some jeans. If x is the number of jeans bought, what expression would represent the total cost of x pairs of jeans?

a. $x
b. $29.99
c. $1279.94
d. $29.99x
e. $6x

6. If x represents Tony's present age in years, then the expression 2(x - 7) would represent which of the following statements?

a. Tony's age seven years from now
b. twice Tony's age seven years from now
c. Tony's age seven years ago
d. twice Tony's age seven years ago
e. seven years less than twice Tony's age

7. The solution of $2(4x - 7) = 5x + 10$, x is in R, is

a. 5 2/3
b. 1
c. 1 1/3
d. 1 11/13
e. 8

8. Solve for x, x is in Q, $3x + 1.25 = x - 4.25$

a. 2.75
b. 3.25
c. -3.25
d. -2.75
e. -1.5

9. A math teacher's solution for an equation was shown as below. In which step does an error occur?

a. $2x + 3 + x - 5 = 2(1 - x) + 3$
b. $3x - 2 = 2 - 2x + 3$
c. $3x - 2 = 5 - 2x$
d. $5x - 7 = 0$
e. $x + -7 / 5$

10. Which of the following equations would not lead to a correct solution of $2 - 3x = 12 - 2(x - 8)$?

a. $2 - 3x = -2x - 4$
b. $2 - 3x = 12 - 2x + 16$
c. $x + 26 = 0$
d. $2 - 3x = 28 - 2x$
e. $-x = 26$

11. Which of the following equations could be used to determine 3 consecutive integers whose sum is 99?

a. $x + 2x + 3x = 99$
b. $x + (x + 1) + (x + 2) = 99$
c. $x + (x + 2) + (x + 4) = 99$
d. $(2x + 1) + (2x + 3) + (2x + 5) = 99$
e. $x - y = 1$

12. The perimeter of the orangutang's rectangular pen was 36 m. If the length was 10 m, what was its width?

a. 26 m
b. 16 m
c. 13 m
d. 9 m
e. 8 m

13. Given that the angle sum of a triangle is 180^0, determine the measure of angle RTS.

a. 50^0
b. 55^0
c. 75^0
d. 45^0
e. 20^0

14. In six years a pet rattlesnake will be twice its present age. What is the snakes present age?

a. 5 years
b. 10 years
c. 6 years
d. 12 years
e. 24 years

15. John worked 48 hrs and his gross pay was $748.80. If he received overtime wages as 1.5 times his regular hourly wage for 8 hours, what was his regular hourly wage?

a. $15.60/h
b. $10.40/h
c. $18.72/h
d. $13.37/h
e. $14.40/h

16. Ima Broke has 4 more nickels than quarters. If the total value of the coins is $2.60, How many quarters does Ima have?

a. 9
b. 20
c. 8
d. 12
e. 7

17. Solve for x: (1/3)x + 2 = 5, x is in R

a. 4 1/3
b. 1
c. 9
d. -9
e. -1

18. Determine the rational number x such that 2x/ 3 + 1/5 = 2/15

a. -0.1
b. 2/ 5
c. -10
d. 10
e. 0.1

19. An approximation, correct to the nearest tenth, for the solution of $4x/5 + 2/3 = x/6$ is

a. -1.0
b. 1.1
c. -0.9
d. -1.1
e. 0.9

20. Students were asked to determine if the numbers 2, -3 and 4 were solutions to the equation $3x^2 + 3x - 18 = 0$. Their conclusion should be that:

a. Only 2 is a solution
b. Only -3 is a solution
c. Both 2 and -3 are solutions
d. Only 4 is a solution
e. Both -2 and 3 are solutions

21. 144 is divided into two parts so that the smaller part is one third of the larger part. The larger part is:

a. 36
b. 48
c. 96
d. 108
e. 72

22. If $(x + 4)/4 - (x - 1)/3 = (x + 5)/2$, x is in Q, then x =

a. 5/7
b. 1 2/5
c. 2
d. -2
e. -5/7

23. Solve for x: $(x+1)/2 + (x+2)/3 = (2x+3)/4$, x is in R

a. 0
b. 1 1/3
c. -1.25
d. 1.25
e. -1 1/3

24. Two years ago Ajin S. Low was 3/4 as old as he will be in five years. What is Ajin's present age?

a. 21 a
b. 23 a
c. 28 a
d. 9 a
e. 14 a

25. Sue won a $1000 prize at Klondike Days. She invested some at 10% and the rest at 9%. At the end of a year total interest was $94. How much did she invest at 10%?

a. $40
b. $54
c. $400
d. $1000
e. $600

APPENDIX 3

Impact of Time Variables on the Design of the Audio Study

This appendix includes a discussion on how other *time* related variables identified in the literature reviewed, effected the design of the *CBIaudio* for Math*Tech 10* Unit 3 Topic 1.

Test-Site Conditions: Ramifications for CBIaudio module development

The Lab at the test-site high school consisted of 30 networked MacClassics with 4MB of RAM memory, and approximately 20MB hard drive file space. The test-site's choice of hardware and software placed several restrictions on the options available for the development of the *CBIaudio* module for this study. Specifically, these were:

1. network conditions, and
2. available RAM and hard drive space.

Network conditions. In earlier field tests (November, 1991) on a University of Alberta Appleshare network, it took up to 12 minutes to load and execute eight Mathematics 10 questions with an accompanying redundant digital audio component. Without the digital audio component, the file access time for the same eight questions (full-text) averages less than one minute. Therefore, to minimize digital audio file *access time*, the *CBIaudio* module was loaded and was run in a stand-alone mode on each of the thirty MacClassics.

Available RAM and hard drive space. Test-site hard drive file space was another parameter that had an impact on the audio research study. In an earlier field test, (November, 1991), adding redundant digital audio to 8 Mathematics 10 questions increased the file size by a factor of approximately ten from approximately 450K to 4.5MB. This ratio was approximated again in July, 1993 when the actual Math*Tech 10* Unit 3 Topic 1 module voice files for this audio study were developed after extensive preliminary testing. Without sophisticated and expensive compression technologies, one second of digital audio requires anywhere from 5 to 22 kilobytes of memory. One megabyte of memory is required to store 45 seconds of medium quality audio (Bove and Rhodes, 1990).

As outlined in Chapter III, the three units of audio (*CBIaudio*) required 17 megabytes of file space for just one small module (Math*Tech 10* Unit 3 Topic 1 Lessons 1, 2 and 3)

Secondly, the RAM constraints inherently imposed by the pilot test site, made it unfeasible to use the most current version of Authorware Professional (AP

2.01) available at the time of this study in the integration of audio into the existing Math*Tech 10* module. AP 2.01 alone (without System 7 RAM needs), required 5MB to run properly. AP 1.7.1 only required 1.5MB of RAM which was well within the test-site's parameters.

Authorware Professional 2.01, with its built in audio compression ability, clearly had some advantages over AP 1.7.1 for use in a research study on the effectiveness of a supplementary digital audio component. AP 2.01 could compress audio files (recorded at 22 KHz) to either a 6:1 or 3:1 ratio. Due to the parameters under which this audio study had to function, the voice files were recorded at 11 KHz which was acceptable telephone quality speech.[6] Given that the voice files were delivered on low end MacClassic computers with mono speakers, this was well within acceptable range. Ideally, if a networked Lab of Quadra 800 were available as a test-site, this research study could have included much higher voice quality audio files while still retaining (or even bettering) access time, delivery time, and storage needs. Therefore, the results of this study are delimited by these important parameters.

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6 Barron (1991) did a preliminary informal survey to determine sampling rates being used at the time of her study, by major developers of CBT programs. She found that most companies recommended using a 7-8 KHz to a 12 KHz sampling rate for human voice digital audio (p.16).

APPENDIX 4

Two-Factor Analysis of Variance of *Initial Load Time (Seconds)*

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F	P
Treatment *CBIaudio/CBItext*	1	346147.03	346147.03	31.06	.00
Ability *HEMS/LEMS*	1	27632.18	27632.18	2.48	.12
Ability X Treatment	1	177.76	177.76	.02	.90
Error	77	858243.27	11146.016		

APPENDIX 5

Summary Table of Analysis of Variance
On *Practice Exercise Time (Seconds)*

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	6160072.44	6160072.43	6.05	.02
Within Groups	80	81394117.39	1017426.48		
Total	81	87554189.83			

GROUP	N	MEAN	SD	SE	95 %CONF INT
CBItext	41	2663.59	1196.06	186.79	2286.06 - 3041.10
CBIaudio	41	2115.42	777.36	121.40	1870.05 - 2360.78
Total	82	2389.50	1039.67	114.81	2161.06 - 2617.94

APPENDIX 6

Summary Table of Analysis of Variance of HEMS's Practice Exercise Times by Treatment (Seconds)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	4327011.03	4327011.03	5.16	.02
Within Groups	38	31853109.14	838239.71		
Total	39	36180120.17			

GROUP	CNT	MEAN	STAND DEV	STAND ERROR	95 %CONF INT
CBItext	20	2723.55	1147.45	256.58	2186.52 - 3260.57
CBIaudio	20	2065.75	599.87	134.14	1785.00 - 2346.50
Total	40	2394.65	963.17	152.29	2086.61 - 2702.69

Summary Table of Analysis of Variance of LEMS's Practice Exercise Times by Treatment (Seconds)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	2067709.93	2067709.93	1.6775	.20
Within Groups	40	49304288.32	1232607.21		
Total	41	51371998.25			

GROUP	CNT	MEAN	STAND DEV	STAND ERROR	95 %CONF INT
CBItext	21	2606.47	1266.21	276.31	2030.10 - 3182.85
CBIaudio	21	2162.71	928.396	202.59	1740.11 - 2585.32
Total	42	2384.60	1119.36	172.72	2035.78 - 2733.41

APPENDIX 7

Summary Table of Two-Factor Analysis of Variance
Of Total Connect Time (Seconds)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F	P
Treatment *CBIaudio/CBItext*	1	44716	44716.42	.02	.90
Ability *HEMS/LEMS*	1	32606	32606.32	.01	.91
Ability X Treatment	1	155846	1558467.00	.61	.44
Error	77	195016738	2532684.91		

APPENDIX 8

Summary Table of Two-Factor ANOVA
of Multiple Choice Final Exam Scores

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F	P
Treatment *CBIaudio/CBItext*	1	10.94	10.94	.09	.77
Ability *HEMS/LEMS*	1	159.26	159.26	1.26	.27
Ability X Treatment	1	157.89	157.89	1.25	.27
Error	77	9742.37	126.52		

APPENDIX 9

Summary of Analysis of Variance
Of LEMS' Practice Exercise Scores

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	32.36	32.36	.09	.77
Within Groups	40	14472.88	361.82		
Total	41	14505.24			

APPENDIX 10

Summary Table of Analysis of Variance
HEMS/LEMS* within *CBIaudio* Overall *Expressed Attitude

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	542.28	542.28	5.15	.03
Within Groups	39	4105.48	105.27		
Total	40	4647.75			

GROUP	N	MEAN	SD	SE	95 %CONF INT
CBItext	20	54.65	10.34	2.31	49.81 - 59.49
CBIaudio	21	61.93	10.18	2.22	57.29 - 66.56
Total	41	58.38	10.78	1.68	54.98 - 61.78

Summary Table of Analysis of Variance
HEMS/LEMS* within *CBItext* Overall *Expressed Attitude

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	P
Between Groups	1	188.45	188.45	2.54	.12
Within Groups	39	2895.77	74.22		
Total	40	3084.21			

GROUP	N	MEAN	SD	SE	95 %CONF INT
CBItext	20	55.51	9.19	2.05	51.21 - 59.81
CBIaudio	21	59.80	8.04	1.75	56.14 - 63.46
Total	41	57.71	8.78	1.37	54.94 - 60.48

APPENDIX 11

Opinion on Learning Mathematics by Computer

1. The method by which I was told whether I had given a right or wrong answer became monotonous.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

2. Nobody really cared whether I learned the course material or not.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

3. I felt challenged to do my best work.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

4. I felt isolated and alone.

All the Time	Most of the Time	Some of the Time	Seldom	Never

5. I felt as if someone were engaged in conversation with me.

All the Time	Most of the Time	Some of the Time	Seldom	Never

6. As a result of having studied by this method, I am interested in learning more about mathematics.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

7. I was more involved in operating the computer than in understanding the course material.

All the Time	Most of the Time	Some of the Time	Seldom	Never

8. The learning was too mechanical.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

9. I felt as if I had a private tutor.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

10. The computer made it difficult to concentrate on the course material.

All the Time	Most of the Time	Some of the Time	Seldom	Never

11. The situation of learning by computer made me quite tense.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

12. Computer-assisted instruction, as used in this course, is an inefficient use of the student's time.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

13. My feeling toward Math 10 at this time is favourable.

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

14. I felt frustrated by the situation.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

15. I f[illegible]d the computer assisted instruction approach in this course to be inflexible.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

16. Material which is otherwise interesting can be boring when presented by CAB.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

17. I was satisfied with what I learned while taking the course.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

18. Given the amount I learned, this method seems better than classroom instruction for many courses.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

19. I would prefer computer assisted instruction to traditional instruction.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

20. Computer assisted instruction is just another step towards de-personalized instruction.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

21. I was concerned that I might not be understanding the material.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

22. The responses to my answers seemed appropriate.

All the Time	Most of the Time	Some of the Time	Seldom	Never

23. I felt uncertain as to my learning in the computer course relative to the learning of others.

All the Time	Most of the Time	Some of the Time	Seldom	Never

24. I was not concerned when I missed a question because nobody was watching me.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

25. I found myself trying to get through the material rather than trying to learn.

All the Time	Most of the Time	Some of the Time	Seldom	Never

26. I knew whether I was right or wrong before I was told.

All the Time	Most of the Time	Some of the Time	Seldom	Never

27. When I am trying to learn things, it is important to me to know where I stand relative to others.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

28. I guessed at the answers to some questions.

All the Time	Most of the Time	Some of the Time	Seldom	Never

29. I was aware of efforts to suit the material specifically to me.

All the Time	Most of the Time	Some of the Time	Seldom	Never

30. I was encouraged by the responses given to my answers to questions.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

31. In view of the time allowed for learning, I felt too much material was presented

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

32. I entered wrong answers in order to get more information from the computer.

All the Time	Most of the Time	Some of the Time	Seldom	Never

33. I felt I could work at my own pace.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

34. Questions were asked which I felt were not related to the materials presented.

All the Time	Most of the Time	Some of the Time	Seldom	Never

35. I was aware of the slow speed of the computer while I was taking the course.

All the Time	Most of the Time	Some of the Time	Seldom	Never

36. Material which is otherwise boring can be interesting when presented by CAB.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

37. I could have learned more if I hadn't felt pushed.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

38. I was given answers but still did not understand the questions.

All the Time	Most of the Time	Some of the Time	Seldom	Never

39. The course material was presented too slowly.

All the Time	Most of the Time	Some of the Time	Seldom	Never

40. The responses to my answers seemed to take into account the difficulty of the question.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

41. While on computer assisted instruction, I encountered mechanical malfunctions.

All the Time	Most of the Time	Some of the Time	Seldom	Never

42. Computer assisted instruction did not make it possible for me to learn quickly.

Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

43. How many weeks have you used computer assisted instruction to study Math 10.

(a) Less than 1 week.
(b) Between 1 and 2 weeks
(c) Between 2 and 3 weeks
(d) Between 3 and 4 weeks
(e) More than 4 weeks

44. On average, how many times do you use a computer for word processing, math or for completing school assignments (at home or at school)?

(a) Almost every day
(b) Less than 3 times per week
(c) Less than 1 time per week
(d) Less than once per month
(e) Almost never

45. What did you like best about CBI Math 10, Unit3, Topic1 (Solving Linear Equations)?

46. What did you like least about CBI Math 10, Unit3, Topic 1 (Solving Linear Equations)?

Thank you for your opinion on learning mathematics by computer. This information will be used to help refine the program. Your opinion will be used for research purposes. It will not be used by your teacher to assign a grade nor will it be shown to anyone with your name on it.

Mathematics 10
Opinion Towards Math By Computer

Thanks for sharing your opinion with us.

APPENDIX 12

Attitude Questionnaire Within Effects, Discussion

The third level of analysis was conducted primarily to address Hypothesis 6. Eight individual questionnaire items evoked significantly different responses from *HEMS/LEMS* subjects within the *CBIaudio* but did not elicit significant differences within the *CBItext* comparison condition. Each of the eight questions are summarized and discussed in turn. Ramifications of the findings are collectively summarized and offered at the end of the section.

Question 8: "The learning was too mechanical." To ensure consistency of direction of responses (positive), this item was recoded before scoring to reverse the scores from a measure of negative orientation to a positive one. That is, responses that "Strongly Disagree" with the statement were assigned a weighted value of 5, while responses that "Strongly Agree" were given a weighted score of 1.

HEMS/CBIaudio subjects had a mean average weighted score of 2.4 while *LEMS/CBIaudio* had a score of 3.4. Analysis revealed that *HEMS/LEMS* average weighted scores differed significantly (p=.00) whereas, they did not show significant differences within *CBItext* (p.=.25).

Observations revealed that mild polarization of the two aptitude groups responses appeared to have occurred with respect to this question. That is, the addition redundant audio to the lesson portion of Math*Tech 10* appeared to make subjects from the two aptitude groups express slightly more polarized views about the "mechanicalness of the learning". *HEMS* subjects within *CBIaudio* appear to view the learning as relatively more mechanical in nature as compared with *LEMS* subjects who viewed it as less so.

Question 9: "I felt as if I had a private tutor." Weighted responses to Question 9 varied significantly (p.=.01) with *LEMS* expressing a directionally more positive attitude and *HEMS* expressing a more negative one. Once again this effect was not observable within *CBItext* where responses did not vary significantly (p.=.19).

This finding seems to suggest that *LEMS* appeared to react to and interpret the addition of *CBIaudio* audio voice files in a more personal way as compared to the *HEMS* who may have viewed the addition of audio as more interfering and less positive in nature.

Question 10: "The computer made it difficult to concentrate on the course material." The scaled responses to this third questionnaire item ranged from "All the time" with a weighted score of 1, to "Never" with a weighted score of 5. Once again, significant polarization of responses occurred within *CBIaudio* (p=.00) but not within *CBItext* (p=.09). *LEMS* expressed a relatively more positive attitude (average mean score of 3.7) by responding within the mean response of "Some of the time" to "Seldom" and *HEMS* expressed a more negative view (average mean score of 2.7) responding within the mean response of "Most of the time" to "Some of the time".

This finding seems to suggest that *LEMS* appeared to react to and interpret the addition of *CBIaudio* voice files as enhancing their ability to concentrate, as compared to the *HEMS* who may view the addition of audio as more interfering and generally, less positive in nature.

Question 15: "I found the computer assisted instruction approach in this course to be inflexible." The scaled responses to the fourth questionnaire item ranged from "Strongly Agree" with a weighted score of 1, to "Strongly Disagree" with a weighted score of 5. Once again, significant mild polarization of responses occurred within *CBIaudio* (p=.02) but not within *CBItext* (p=.13). *LEMS* expressed a relatively more neutral attitude (average mean score of 3.0) by responding within the mean response of "Uncertain", whereas *HEMS* expressed a relatively more negative view (average mean score of 2.25) responding within the mean response of "Agree" to "Uncertain".

This finding seems to suggest that *LEMS* appeared to react to and interpret the addition of *CBIaudio* voice files in a more neutral fashion with respect to the flexibility of the approach as compared to the *HEMS* who may have viewed the addition of audio as relatively more inflexible and less positive in nature.

Question 17: "I was satisfied with what I had learned while taking the course." The scaled responses to the fifth questionnaire item were recoded in a positive direction and ranged from "Strongly Disagree" with a weighted score of 1, to "Strongly Agree" with a weighted score of 5. Once again significant mild polarization of responses occurred within *CBIaudio* (p=.00) but not *CBItext* (p=.22). *LEMS* expressed a relatively more positive attitude (average score of 3.2) by responding within the mean average range of "Uncertain" to "Agree", whereas *HEMS* expressed a relatively more negative view (average score of 2.20) responding within the mean average range of "Disagree" to "Uncertain".

This finding seems to suggest that *LEMS* appeared to be relatively more satisfied with their own learning of the dual-channel lesson material as compared to the *HEMS* who, as hypothesized, expressed relatively less satisfaction within *CBIaudio*

Question 31: "I was concerned that I might not be understanding the material." The scaled responses to the sixth questionnaire item ranged from "Strongly Agree" with a weighted score of 1, to "Strongly Disagree" with a weighted score of 5. Once again significant polarization of responses occurred within *CBIaudio* (p=.00) but not within *CBItext* (p=.86). *LEMS*, as might be expected, expressed some concern about their understanding of the material (average mean score of 2.4) by responding within the mean range of "Agree" to "Uncertain".

Ironically, however, *HEMS/CBIaudio* subjects expressed relatively more concern about their understanding of the material (average mean score of 1.5) responding within the mean range of "Strongly Agree" to "Agree". Interestingly enough, although *both HEMS/LEMS* within *CBItext* did express concern regarding their understanding of the material, this effect was not significant (p.=.86) nor as mildly polarized as the effect within *CBIaudio*.

This finding seems somewhat puzzling and difficult to interpret. Perhaps the addition of a human voice in the lesson and feedback portion of the module, resulted in *HEMS* subjects becoming more critical of their own work and less self-assured. It appeared to produce a different effect for *LEMS* subjects. *LEMS/CBIaudio* subjects appeared to be more unwillingly to take a stand on this issue, that is, to either outright "Agree" or "Disagree" with the statement. Therefore, they elected on average to describe their state with respect to this question as "Uncertain".

Question 32: "I entered wrong answers in order to get more information from the computer". Analysis of the seventh questionnaire item in this section produced interesting results. The Likert scale responses to this item ranged from "All the time" with a weighted score of 1, to "Never" with a weighted score of 5. Within *CBItext*, both aptitude groups (*HEMS/LEMS*) responded on average with identical mean weighted scores (4.0 or "Seldom") producing a F probability of 1.

Within *CBIaudio*, a mild polarization of responses once again appears to have occurred. *LEMS* subjects admitted that they employed this strategy (average mean score of 3.7) by responding with the selection of descriptions of "Some of the time" (leaning towards "Seldom"), whereas *HEMS* subjects claimed that they "Seldom" (leaning towards "Never") (average mean score of 4.4) employed the strategy.

What is it about the addition of redundant audio in the lesson and feedback portion of the Math*Tech 10* module that would encourage this type of differentia response by the two different aptitude groups? One could speculate that the addition of the human voice and therefore the perceived personalization of the computer, encourages subjects to either be more honest in admitting that they did actually employ this strategy or alternately, to be less likely to employ this strategy because they felt less comfortable cheating on the computer. In order to test these speculations or to fully understand why the mild polarization occurred, further studies tracking the number of times incorrect information was actually entered into the computer correlated with similar attitude questionnaire items would have to be conducted.

Question 42: "Computer assisted instruction did not make it possible for me to learn quickly." The eighth and final questionnaire item that elicited significant different responses within *CBIaudio* by *HEMS/LEMS* groups, was Question 42. The scaled responses to Question 42 ranged from "Strongly Agree" with a weighted score of 1, to "Strongly Disagree" with a weighted score of 5. Once again, significant polarization of responses occurred within *CBIaudio* (p=.04) but not within *CBItext* (p=.17). *LEMS/CBIaudio* subjects expressed a relatively more neutral attitude (average mean score of 2.8) by responding with the mean response of slightly below "Uncertain". *HEMS/CBIaudio* subjects expressed a more pronounced negative view (average mean score of 2.2) responding within the mean response of "Agree".

This finding seems to suggest that *LEMS* subjects appeared to react in a more neutral fashion with respect to their perceived ability to learn quickly with CAI (with audio). *HEMS* subjects on the other hand, appeared to view CAI (with audio) as not enhancing their ability to learn quickly. This finding is in keeping with other findings from the questionnaire items in which *HEMS/CBIaudio* subjects tended to express more negative reactions to *CBIaudio*.

APPENDIX 13

Attitude Survey Questions 43 and 44 Findings

Question 43 — *How many weeks have you used computer assisted instruction to study Mathematics 10 or Mathematics 13 (this year or in past years)?*

Question 44 — *On average, how many times do you use a computer for word processing, math or for completing school assignments (at home or at school)?*

Responses to Questions 43 and 44 were used to determine if subjects met the computer and the Math*Tech 10* familiarity criteria operationally defined in Chapter I in order to control for confounding Hawthorne effects. TABLE 40 and 41 indicates the subjects reported range of pre-study experience in each of the areas, respectively.

TABLE 40
Reported Pre-Audio Study Frequency Use of Math*Tech 10*

Frequency	< 1 week	1 to 2 wks.	2 to 3 wks.	3 to 4 wks	>4 weeks
CBItext	20	13	6	1	1
CBI audio	20	17	4		

S=82

TABLE 40 indicates that 20 students in *CBIaudio* and *CBItext* reported the time they had to become familiar with the protocol of Math*Tech 10* as less than one week. As described in Chapter III, all classes were given a minimum of one week's exposure or more to the networked version of Math*Tech 10* in the presence of the researcher.

Students decision to report less than one week on this item, may indicate how unfamiliar they felt with Math*Tech 10* protocol despite their pre-session experiences. (Interestingly enough, subjects observed behaviour during the actual study and questions posed by them throughout the study, did not indicate that this was a potential area of weakness.) It is however, acknowledged as a possible delimiting factor. Ideally it would have been preferable to have the students spend more time with Math*Tech 10* materials before participating in the audio study. Due to unforseen and unavoidable problems in the lab test-site, this pre-condition was not able to be met as originally agreed upon through no fault of the participating parties involved.

TABLE 41
Reported Pre-Audio Study Frequency of Computer Use

Frequency rating	almost every day	< 3 times per week	< once per week	< once per month	almost never
CBItext	2	7	12	9	11
CBI audio	5	8	11	2	15

S=82

TABLE 41 demonstrates that the majority of subjects met the minimum requirements as outlined in the operational definition of experienced computer user in Chapter I. It is interesting to note that some students in both treatment conditions described themselves as almost never using computers for other school work at school or at home.

During pre-study Math*Tech 10* protocol demonstrations conducted by the researcher, an informal show of hands indicated that all subjects had previous computer knowledge and did not feel the need for further tutorial instruction on the general usage of a computer. It was therefore interesting to tabulate these results and encounter this response. If the responses do reflect an accurate reporting of subjects' computer usage (as opposed to a measure of their dislike of computers in general), this apparent failure to meet minimum prior computer familiarity standards, could potentially have resulted in confounding effects which would have an impact on the studies' reported findings. It is therefore acknowledged as a possible delimiting factor.

However, it is likely that subjects in the study had prior access to computers at home or through their friends given the nature of the community in which they live. It might have been better to directly ask the subjects to estimate how many previous experiences they had on a computer (ie. games, e-mail, networking, etc.) to get a more accurate indication of their prior computer knowledge so that the novelty effect associated with computers could have been more accurately screened for and documented.

APPENDIX 14

<u>Copyright Release For MathTech 10, Unit 3</u>

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Edmonton

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633 Education South, Telephone (403) 492-3678
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Date: 6 August 1993

To: Darlene Rehaag
From: Michael Szabo

I authorize the use of Unit 3 of Mathtech10 for your masters research in conjunction with a school district of your choice. This permission includes modification of any or all of the lessons in Unit 3, primarily by adding redundant audio, so they meet the purposes of the research proposal which has been approved by the Faculty of Education.

The conditions that apply to this release are that the materials will be protected from copying or other distribution and removed from any experimental site where they will be used for the research and that a copy of the modified lessons will be submitted to me on or before the completion of the degree.

Good luck on your research.

Michael Szabo

APPENDIX 15

<u>Activities Overview for Math*Tech 10*</u>

Activities Overview for Math*tech 10* Educational Courseware, Version 2.0

UNIT 1 NUMBER SYSTEMS

Topic 1: Rational Number System

Activity 1: Identify repeating or terminating decimals as rational numbers
Activity 2: Change fractions to decimals and percents
Activity 3: Change terminating decimals to fractions and percents
Activity 4: Recognize fractional equivalents of common repeating decimals (thirds, sixths, ninths)

Topic 2: Irrational Number System

Activity 1: Recognize irrational numbers as infinite, non-repeating decimals
Activity 2: Find approximations for square roots of non-perfect squares
Activity 3: Evaluate square roots and define the square roots of negative integers as imaginary numbers
Activity 4: Recognize π as a special irrational number

Topic 3: Relationships Among Number Systems

Activity 1: Identify real numbers as the union of the rational and irrational numbers, and locate real numbers on a number line
Activity 2: Identify complex numbers as the union of real and imaginary numbers
Activity 3: Use absolute value to find the distance between points on a number line

UNIT 2 OPERATIONS ON POLYNOMIALS

Topic 1: Polynomial terminology	**Activity 1:** Identify the following as they occur in the study of polynomials: term, variable, factor, monomial, binomial, trinomial, polynomial, numerical, coefficient, literal coefficient, degree, exponent, base, and power **Activity 2:** Classify polynomials according to degree and number of terms **Activity 3:** Arrange polynomials in descending powers
Topic 2: Evaluating Polynomials	**Activity 1:** Evaluate polynomials for given values of the variable **Activity 2:** Write polynomials as rules which describe mathematical situations
Topic 3: Laws for Exponents	**Activity 1:** Use the Multiplication Law of exponents for power with literal bases and whole number exponents **Activity 2:** Use the Power of a Power Law for exponents **Activity 3:** Use the Division Law of exponents for power with literal bases and whole number exponents **Activity 4:** Use the Power of a Product Law for exponents **Activity 5:** Use the Power of a Quotient Law for exponents
Topic 4: Zero and Negative Exponents	**Activity 1:** Use zero exponents **Activity 2:** Use negative exponents
Topic 5: Scientific Notation	**Activity 1:** Multiply and divide using scientific notation
Topic 6: Adding and Subtracting Polynomials	**Activity 1:** Add & Subtract polynomials
Topic 7: Multiply Polynomials	**Activity 1:** Use Algebraic tiles to multiply polynomials **Activity 2:** Multiply polynomials by monomials **Activity 3:** Multiply binomials by binomials

Topic 8:
Dividing Polynomials

Activity 1: Divide polynomials by monomials
Activity 2: Divide polynomials by binomials of the form ax + b

UNIT 3 EQUATIONS AND INEQUALITIES

Topic 1:
Solving and Verifying Linear Equations

Activity 1: Translate English into Algebra
Activity 2: Solve and verify simple linear equations with integral coefficients
Activity 3: Solve and verify simple linear equations with rational coefficients
Topic 2: Inequalities
Activity 1: Solve, graph and verify any linear inequalities which have rational coefficients, and apply the "Reverse the Sign" rule as needed
Activity 2: Solve word problems with linear inequalities

Topic 3:
Simple Quadratic and Radical Equations

Activity 1: Solve and verify simple quadratic equations which are easily reducible to $x^2 = a$
Activity 2: Solve and verify simple radical equations which are easily reducible to $\sqrt{x} = b$

UNIT 4 FACTORING POLYNOMIALS

Topic 1:
Removing Common Factors

Activity 1: Factor a polynomial which has a common monomial factor.
Activity 2: Factor a polynomial which has a common binomial factor.

Topic 2:
Factoring

Activity 1: Factor trinomials of the form $ax^2 + bx + c$, where a,b,c, are in I, using algebraic tiles.
Activity 2: Factor trinomials of the form $ax^2 + bx + c$, where a,b,c, are in I.
Activity 3: Factor trinomials of the form $ax^2 + bx + c$, where a, b, c, are in I, using greatest common factors.
Activity 4: Factor trinomials of the form $ax^2 + bx + c$ where a is some integral value other than 1.
Activity 5: Factor a perfect square trinomial.

Activity 6: Recognize and factor a difference of squares binomial.
Activity 7: Factor polynomials which require a combination of methods in order to be completely factored.

Topic 3: Solving Equations by Using Factoring

Activity 1: Find, by factoring, the rational zeros of an integral quadratic polynomial in one variable.
Activity 2: Solve, by factoring, quadratic equations with integral coefficients in one variable.
Activity 3: Solve problems which can be represented by factorable quadratic equations.

UNIT 5A COORDINATE GEOMETRY AND GRAPHING

Topic 1: Distance Between Two Points

Activity 1: Use terminology and graphing skills related to the graphing of ordered pairs.
Activity 2: Find the distance between two points.
Activity 3: Develop and use the distance formula to solve problems.

Topic 2: Finding the Midpoint

Activity 1: Develop and use the midpoint formula for finding the midpoint of a line segment.
Activity 2: Solve problems which involve the use of the midpoint formula.

Topic 3: Slope of a Line

Activity 1: Define slope of a line segment as rise over run.
Activity 2: Develop and apply the formula for slope.
Activity 3: Identify and use the relationship between slopes of parallel lines.
Activity 4: Identify and use the relationship between slopes of perpendicular lines.

Topic 4: Collinear Points

Activity 1: Identify conditions for determining collinearity.

Topic 5: Graphing Linear Equations

Activity 1: Develop a table of values and sketch the graph of a linear equation.
Activity 2: Determine x-and y-intercepts

UNIT 5B COORDINATE GEOMETRY AND GRAPHING

Topic 6: Slope and y-intercept

Activity 1: Change the subject in formulas.
Activity 2: Rewrite linear equations in the form y = mx + b and identify the significance of m and b.
Activity 3: Determine the slope and y-intercept of a line from its equation and draw the graph.
Activity 4: Graph linear equations using slope and another point on the line.

Topic 7: Vertical and Horizontal Graphs

Activity 1: Describe and graph equations of lines parallel to the x-axis and parallel to the y-axis.

Topic 8: Equations with Unique Conditions

Activity 1: Rewrite linear equations in the form Ax + By + C = 0.
Activity 2: Determine the equation of a line given the slope and a point on the line.
Activity 3: Determine the equation of a line passing through two given points.
Activity 4: Determine the equation of horizontal and vertical lines.
Activity 5: Determine the equation of a line given one point and the equation of a line parallel or perpendicular to it.

UNIT 6 SYSTEMS OF EQUATIONS

Topic 1: Solving Systems of Equations Graphically

Activity 1: Solve and classify a system of two linear equations by graphing.
Activity 2: Classify a system of two linear equations as dependent, independent or inconsistent according to the slopes and y-intercepts of the equations.

Topic 2: Solving Systems of Equations Algebraically

Activity 1: Solve a system of two linear equations by comparison.
Activity 2: Solve a system of two linear equations by substitution.
Activity 3: Solve a system of two linear equations by addition or subtraction.

Activity 4: Solve a system of two linear equations by any algebraic method.

Activity 5: Solve word problems using any algebraic method.

UNIT 7 TRIGONOMETRY

Topic 1: The Theorem of Pythagoras

Activity 1: Draw and label the sides and angles of a triangle.

Activity 2: Find the length of a side of a given triangle and solve problems by applying the Theorem of Pythagoras.

Topic 2: Properties of Similar Triangles

Activity 1: Solve problems involving the sum of the angles of a triangle.

Activity 2: Recognize and write the similarity relationship between similar triangles.

Activity 3: Solve problems by using the properties of similar triangles.

Topic 3: Developing Trigonometric Ratios

Activity 1: Define the terms: opposite side, adjacent side and hypotenuse.

Activity 2: Use the properties of similar triangles to develop the tangent, sine and cosine ratios.

Topic 4: Finding Trigonometric Ratios

Activity 1: Determine the sine, cosine and tangent ratios and the measures of the acute angles within right triangles, given the measure of any two sides.

Topic 5: Applying Trigonometric Ratios

Activity 1: Determine the measure of an acute angle, given its sine, cosine or tangent ratio.

Activity 2: Apply trigonometric ratios to determine the measure of an angle of a given right triangle.

Activity 3: Apply trigonometric ratios to determine the length of a side in a given right triangle.

Activity 4: Apply trigonometric ratios to solve right triangles.

Activity 5: Apply trigonometric ratios to solve word problems involving an unknown side or angle of a right triangle.

UNIT 8 STATISTICS

Topic 1: Collection of Data

Activity 1: Analyze problems and generate and collect data appropriately.
Activity 2: Identify samples along with the populations from which they are taken.
Activity 3: Evaluate samples for bias, appropriateness of sample type and randomness.

Topic 2: Organization and Presentation of Data

Activity 1: Organize data using tables.
Activity 2: Organize data using stem-and-leaf plots.
Activity 3: Organize data using tables box plots.
Activity 4: Graph data and interpret data graphed on pictographs.
Activity 5: Graph data and interpret data graphed on bar graphs.
Activity 6: Graph data and interpret data graphed on circle graphs.
Activity 7: Graph and interpret continuous data using histograms.
Activity 8: Graph and interpret continuous data using frequency polygons.

Topic 3: Analysis of Data: Mean, Median, Mode

Activity 1: Define the measures of central tendency and determine the most suitable measure of central tendency for a given set of data.
Activity 2: Determine the following for discrete raw data: mean, median, and mode.
Activity 3: Determine the following for tabular data: mean, median, and mode.
Activity 4: Determine the range for a given set of data.

Topic 4 : Drawing Inferences

Activity 1: Compare and contrast two (or more) sets of data which address similar situations.
Activity 2: Identify the vocabulary of probability as it applies to the likelihood of the occurrence of an event within a sample.
Activity 3: Make a probability statement and show how it relates to a sample and the population.
Activity 4: Comment on the confidence of predictions which are based on the analysis of a sample.